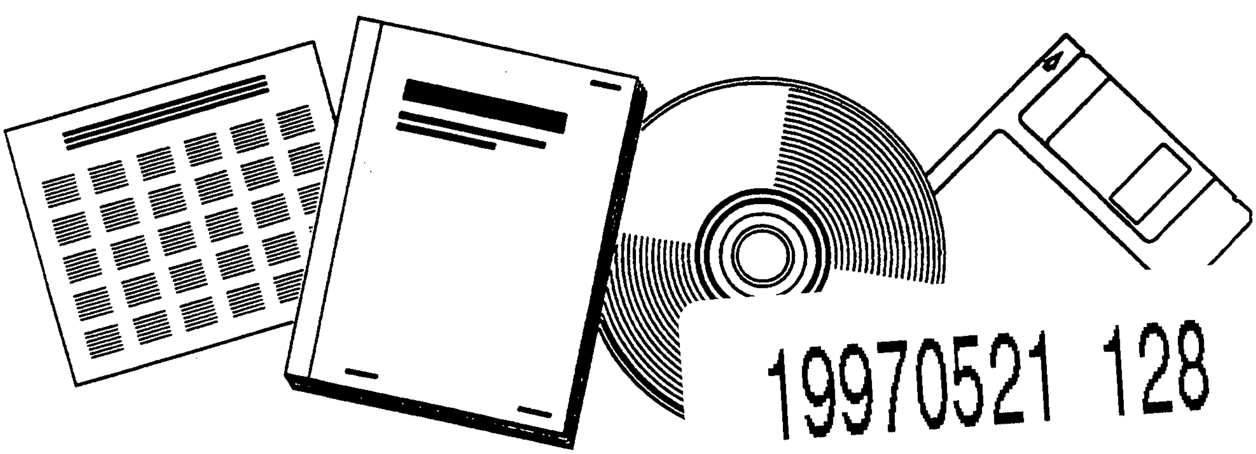
PB93-164249

JAPANESE TECHNOLOGY EVALUATION CENTER WORKSHOP ON ADVANCED MANUFACTURING TECHNOLOGY FOR POLYMER COMPOSITE STRUCTURES IN JAPAN. HELD IN ARLINGTON, VIRGINIA, ON FEBRUARY 18, 1993. VIEWGRAPHS

JAPANESE TECHNOLOGY EVALUATION CENTER
BALTIMORE, MD

FEB 93



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PB93-165249

International Technology Research Institute
Japanese Technology Evaluation Center

JTEC WORKSHOP ON ADVANCED MANUFACTURING TECHNOLOGY FOR POLYMER COMPOSITE STRUCTURES IN JAPAN

Viewgraphs

February 18, 1993

Sponsored by:
National Science Foundation
U.S. Department of Energy
U.S. Army Research Office
U.S. Air Force Office of Scientific Research

Best Western Westpark Hotel
1900 N. Fort Myer Drive
Arlington, VA

JAPANESE TECHNOLOGY EVALUATION CENTER

SPONSOR

The Japanese Technology Evaluation Center (JTEC) is operated for the Federal Government to provide assessments of Japanese research and development (R&D) in selected technologies. The National Science Foundation (NSF) is the lead support agency. Paul Herer, Senior Advisor for Planning and Technology Evaluation, is NSF Program Director for the project. Other sponsors of JTEC include the National Aeronautics and Space Administration (NASA), the Department of Commerce (DOC), the Department of Energy (DOE), the Office of Naval Research (ONR), the Defense Advanced Research Projects Agency (DARPA), the U.S. Air Force, and the U.S. Army.

PURPOSE

JTEC assessments contribute to more balanced technology transfer between Japan and the United States. The Japanese excel at acquisition and perfection of foreign technologies, whereas the U.S. has relatively little experience with this process. As the Japanese become leaders in research in targeted technologies, it is essential that the United States have access to the results. JTEC provides the important first step in this process by alerting U.S. researchers to Japanese accomplishments. JTEC findings can also be helpful in formulating governmental research and trade policies.

APPROACH

The assessments are performed by panels of about six U.S. technical experts. Panel members are leading authorities in the field, technically active, and knowledgeable about both Japanese and U.S. research programs. Each panelist spends about one month of effort reviewing literature and writing his/her chapter of the report on a part-time basis over a twelve-month period. All recent panels have conducted extensive tours of Japanese laboratories. To provide a balanced perspective, panelists are selected from industry, academia, and government.

ASSESSMENTS

The focus of the assessments is on the status and long-term direction of Japanese R&D efforts relative to those of the United States. Other important aspects include the evolution of the technology and the identification of key researchers, R&D organizations, and funding sources.

REPORTS

The panel findings are presented to workshops where invited participants critique the preliminary results. Final reports are distributed by the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 (703-487-4650). Panelists also present their findings in conference papers, journals, and books. All results are unclassified and public.

STAFF

The Loyola College JTEC staff helps select topics to be assessed, recruits experts as panelists, organizes and coordinates panel activities, provides literature support, organizes tours of Japanese labs, assists in the preparation of workshop presentations and in the preparation of reports, and provides general administrative support. Mr. Cecil Uyehara of Uyehara International Associates provided literature support and advance work for this panel.

Dr. Duane Shelton	Mr. Geoff Holdridge	Dr. George Gamota
Principal Investigator	Director	Senior Advisor to JTEC
Loyola College	JTEC/Loyola College	Mitre Corporation
Baltimore, MD 21210	Baltimore, MD 21210	Bedford, MA 01730

PB93-165249

Japanese Technology Evaluation Center

Workshop on Advanced Manufacturing Technology for Polymer Composite Structures in Japan

February 18, 1993
Westpark Hotel
1900 N. Ft. Myer Drive
Arlington, VA 22209

AGENDA

8:30	Registration - Coffee
9:00	Welcome (Shelton, JTEC/WTEC)
9:10	Introduction to JTEC (Herer, NSF)
9:20	Overview and Executive Summary (Wilkins)
9:45	Break
10:00	Aerospace (Ashizawa/Gill)
11:00	Break
11:15	Sporting Goods (McDermott)
11:30	Automotive (McDermott)
11:40	Industrial (McDermott)
11:55	Questions
12:10	Lunch
1:10	Civil Engineering (McDermott/Karbhari)
1:50	Materials (DeVault)
2:10	Break
2:25	Manufacturing Science (Karbhari)
2:50	Product and Process Development Methods (Karbhari)
3:20	Conclusions and Comparisons with U.S. Activity (Panel)
3:50	Questions
4:00	Adjournment

JTEC/WTEC STAFF

R.D. Shelton, Principal Investigator
Michael DeHaemer, Co-Principal Investigator
Geoffrey M. Holdridge, JTEC Director, JTEC/WTEC Series Editor
Bobby A. Williams, Assistant Director
Aminah Batta, Editorial Assistant
Catrina Foley, Secretary

Advance Work in Japan performed by Alan Engel of ISTA, Inc.

The final report of the JTEC Panel on Advanced Manufacturing Technology for Polymer Composite Structures in Japan will be available from the National Technical Information Service (NTIS) of the U.S. Department of Commerce. A list of JTEC/WTEC reports available from NTIS is shown on the inside back cover of this document.

International Technology Research Institute
Japanese Technology Evaluation Center

Panel on Advanced Manufacturing Technology for Polymer Composite Structures in Japan

Panel Members

Dick J. Wilkins (Chair)
Institute for Applied Composites Technology

Moto Ashizawa
Ashizawa & Associates Composite Engineering

Jon B. DeVault
DARPA

Dee R. Gill
McDonnell Aircraft

Vistasp M. Karbhari
Center for Composite Materials (Univ. of Delaware)

Joseph S. McDermott
Composites Services Corporation

International Technology Research Institute
Japanese Technology Evaluation Center

Workshop on Advanced Manufacturing Technology for
Polymer Composite Structures in Japan

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AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

VIEWGRAPHS

Table of Contents

OVERVIEW AND EXECUTIVE SUMMARY

Dick J. Wilkins
Institute for Applied Composites Technology

JTEC WORKSHOP

- Title
- Introduction to Composites
- Common Applications
- Aircraft Applications
- Manufacturing Methods
- Sponsors
- Panel

JTEC WORKSHOP (cont.)

- Sponsor Traveling Representatives
- Mission
- Motivation for Study
- Spirit of Study
- Process
- Schedule
- Logistics

JTEC WORKSHOP (cont.)

- EXECUTIVE SUMMARY
- Overall Findings
- Interesting development areas
- Detailed Findings
- Observations on Japanese Mfg Technology
- Impressions

Title

- Advanced Manufacturing Technology for Polymer Composite Structures

Introduction to Composites

- Definition - A combination of two or more materials that enhances their properties.
- Incentives
  - Stiffness/weight
  - Ability to tailor structural performance
  - Ability to tailor thermal expansion
  - Strength/weight
  - Corrosion resistance
  - Fatigue resistance

Common Applications

- Boats
- Surf Boards
- Fishing Rods
- Racquets
- Skis
- Tool Handles

Aircraft Applications

- Commercial Aircraft flaps, slats, elevators, tails
- Helicopter blades & bodies
- F-16 Tail Surfaces
- F-18 Wings and Tails
- AV-8B Harrier Fuselage, Wings, Tails
- F-117
- B-2

Manufacturing Methods

- Lamination
  - Hand or machine layup of dry of pre-impregnated layers
  - Vacuum bag, press, or autoclave molding
- Pultrusion
  - Continuous pulling of fiber preform through resin bath and heated die
- Filament Winding
  - Dry or wet winding around mandrels

Manufacturing Methods (cont.)

- Compression Molding
  - Press Molding of Structural Molding Compound (SMC)
- Thermoforming
  - Stamping of pre-impregnated fibers and resin
- Liquid Molding (RTM, SRIM, etc.)
  - Injection of resin into mold containing fiber preform

Sponsors

- NSF, Paul Herer
  - JTEC Principal Investigator, Dr. Duane Shelton, Loyola College
  - JTEC Director, Geoff Holdridge, Loyola College
- Army Research Office, Dr. Andrew Crowson
- Air Force Office of Scientific Research, Dr. Charles Lee
- Department of Energy, Dr. Paul Maupin

Panel

- Dick Wilkins (Chair), Institute for Applied Composites Technology
- Moto Ashizawa, Ashizawa & Associates Composites Engineering
- Jon DeVault, DARPA
- Dee Gill, McDonnell
- Vistasp Karbhari, Center for Composite Materials
- Joe McDermott, Composites Services Corp

Dick Wilkins (Chair), Institute for Applied Composites Technology

- 17 years at General Dynamics, Fort Worth in composites development (Coordinator of F-16 Tail Certification)
- 5 years as Director of UD Center for Composite Materials (2 years as President of American Society for Composites)
- 2 years as Director of IACT

Moto Ashizawa, Ashizawa & Associates Composites Engineering

- 15 years in composites design, analysis & development at Douglas
- 10 years in composites program mgmt, certification, & manufacturing at Douglas
- 1 year in composites consulting (Both U.S. & Japan)

Jon DeVault, DARPA

- 25 years experience in advanced materials industry with Hercules
- Former President of Hercules Advanced Materials & Structures Company
- Starting new position organizing composites initiative at DARPA

Dee Gill, McDonnell

- 25 years in manufacturing methods development at Hercules
- 4 years as Director, Production Operations at McDonnell Aerospace

Vistasp Karbhari, Center for Composite Materials

- Associate Scientist, Center for Composite Materials, U of D
- Research Assistant Professor in Civil Engineering, U of Delaware

Joe McDermott, Composites Services Corp

- 11 years as Director, Composites Institue of SPI
- 12 years in composites consulting (Both U.S. & Japan)

Sponsor Traveling Representatives

- Iqbal Ahmad, ARO
  - Excellent background in materials science
  - Army Representative in Japan
- Alan Engel, ISTA
  - Several years in polymer & composites research at Dupont
  - JTEC Advance Arrangements Contractor
- Dana Granville, ARL
  - Army Materials Directorate Coordinator for Composites

Sponsor Traveling Representatives (cont.)

- Bruce Kramer, NSF
  - Program Director for Manufacturing & Materials Processing
- Xavier Spiegel, JTEC
  - Teaches materials

Mission

- To summarize the current status and future outlook in Japan and the United States

Motivation for Study

- U.S. wants to move from invention to commercialization
- Need advancements for low cost, repeatable manufacturing

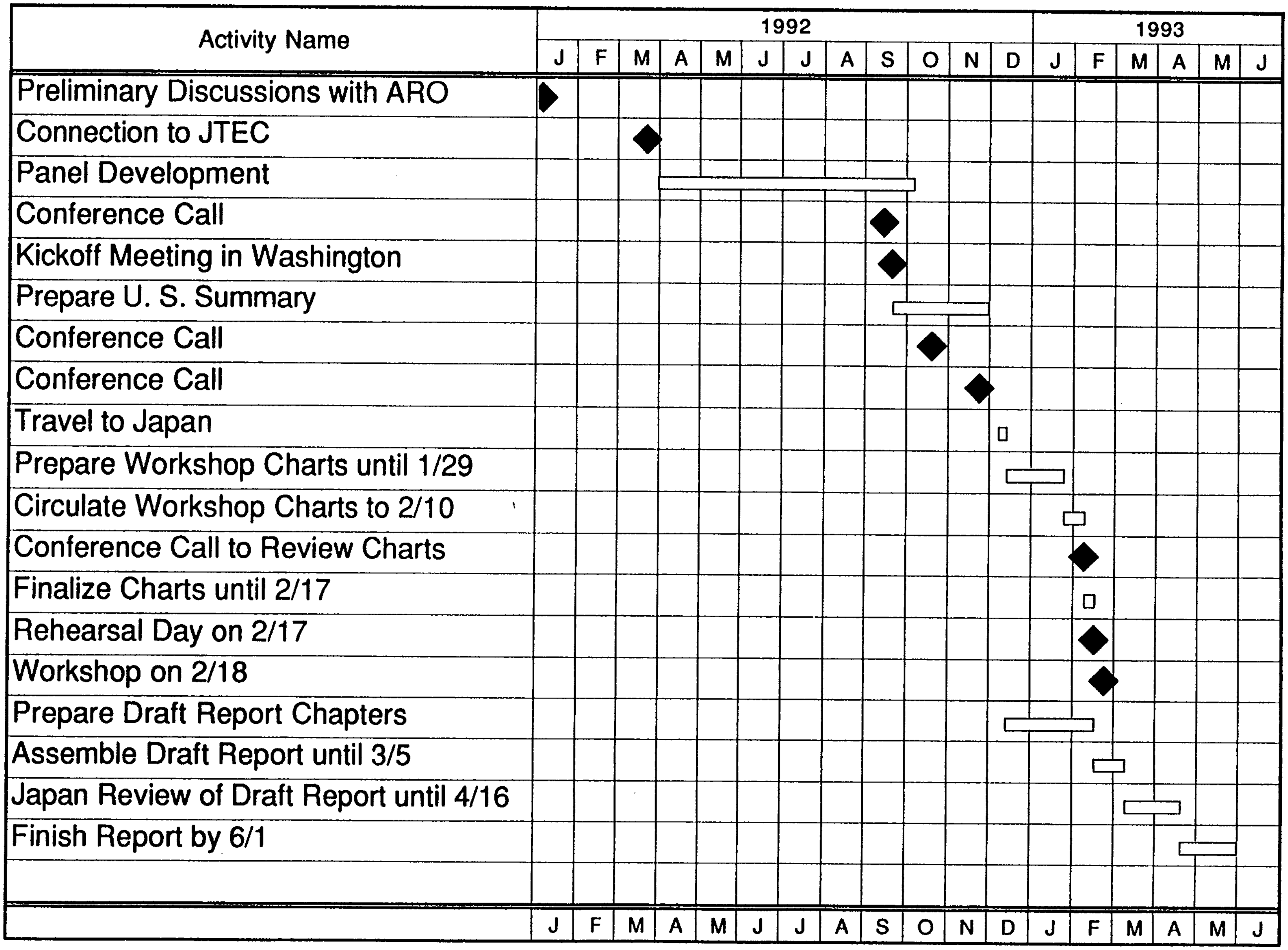
Spirit of Study

- Cooperate to expand markets for composites

Process

- Use literature to summarize U.S. status
- Use literature and key Japan site visits to summarize Japanese status
- Present summary findings at Workshop
- Develop written report

JTEC SCHEDULE



JTEC SITES VISITED

DATE	SITE	LOCATION
S,12/5	Nippon Steel	Kawasaki
Su, 12/6	Kick-off meeting	Tokyo
M,12/7	Mitsubishi Kasei	Yokohama
	Mitsui Toatsu	Ofuna
	NAL	Tokyo
	Tokyo U	Tokyo
	MITI (A/C & Ord)	Tokyo
Tu,12/8	KHI	Gifu
	MHI, Mfg	Nagoya
	MHI, Materials	Nagoya
	Yamaha Motors	Hamamatsu
	Toyota	Gotemba
W,12/9	Kyoto Inst of Tech	Kyoto
	Doshisha U	Kyoto
	Mizuno	Osaka
	Nikkiso	Kaneya
Th,12/10	IPRI	Tsukuba
	RIPT	Tsukuba
	Toray	Matsuyama
	FHI	Utsunomiya
F,12/11	Mitsubishi Elec	Sagamihara
	Shimizu	Tokyo
	JAMCO	Tokyo
	NSF	Tokyo
S, 12/12	Wrap-up Meeting	Tokyo

EXECUTIVE SUMMARY

Overall Findings

- Practice same basic manufacturing technologies.
- Practice with a much greater thoroughness and respect for detail.
- Expressed confidence in the training and skills of work force.
- Developed processes to remove chances for errors and reduce cost.
- Reducing composite detail part count.

Interesting development areas

- Co-cured Omega stringer panels
- 3-D and 2.5-D weaving
- Curved pultrusion
- Continuous forming of thin-walled pipes

Detailed Findings

- Aerospace
- Sporting Goods
- Automotive
- Industrial
- Civil Engineering
- Materials
- Manufacturing Science
- Product and Process Development

Aerospace

- Focused on commercial application of aerospace technology.
- Introduced through alliances with U.S. and European companies.

Sporting Goods

- Looking for better performance at the same cost.
- Trying to move from tape wrapping to low-cost SRIM.

Automotive

- Somewhat stymied by cost and recycling concerns.

Industrial

- Many cost-driven applications are being tried.

Civil Engineering

- In contrast to the US, where the construction industry is fragmented, the Japanese opportunities in civil engineering applications are many and varied.

Materials

- Still trying to introduce pitch carbon fiber into applications, but economics are suspect.
- Emphasizing thermoplastics and high temperature resins, despite recent reduction in US emphasis.

Manufacturing Science

- In contrast to the modeling efforts in the US, Japanese manufacturing science appears to reside in experienced workers who understand the processes over long times.

Product and Process Development

- Japanese product and process development efforts use concurrent engineering by definition.
- Japanese teams have developed the human factors issues far beyond those in the West.

Observations on Japanese Mfg Technology

- Focus more on long-range strategy.
- Invest more in development and training to ensure success.
- Development efforts are application-dominated.
- Accomplish more with less.
- Drive to low cost from a life cycle viewpoint.
- Manufacturing people have high status.
- Are better at consortia and industry-government links. (While the US is better at university-industry links.)
- Will derive cost advantage from government projects in standards and data bases.

Impressions

- Japan and US have much to gain from each other.
- Must develop ways to cooperate.
- Producers are vulnerable to cost reductions obtained from deeper understanding of basic processes.
- Companies must develop a unified basis for understanding how to make repeatable composite structures.
- Process advancements can be transferred to the US only by also transferring the spirit of cooperation that exists within Japanese companies.

AEROSPACE

Dee R. Gill
McDonnell Aircraft

Moto Ashizawa
Ashizawa & Associates Composites Engineering

ADVANCED FABRICATION TECHNOLOGY FOR POLYMER COMPOSITE STRUCTURES

AEROSPACE

PRESENTED BY
MOTO ASHIZAWA
DEE GILL

INTRODUCTION

- RELEVANCE AND BACKGROUND
- HISTORICAL DEVELOPMENT OF AEROSPACE COMPOSITE FABRICATION TECHNOLOGY
- HOW CURRENT EVENTS AFFECTING AEROSPACE
- CURRENT STATUS OF U.S. AND JAPANESE FABRICATION TECHNOLOGY AND APPLICATIONS
- FUTURE FABRICATION TECHNOLOGY
- COOPERATION KEY TO SUCCESSFUL EXPANSION
- SUMMARY AND FINDINGS

RELEVANCE AND BACKGROUND

(PAGE 1)

- AEROSPACE A STRATEGIC INDUSTRY FOR MANY INDUSTRIAL COUNTRIES BECAUSE OF:
  - NATIONAL SECURITY
  - ECONOMIC STRENGTH
  - TECHNOLOGICAL ADVANCEMENT
- UNIQUENESS OF AEROSPACE
  - STILL CONSIDERED AS HAND MADE
  - HIGH $ PER POUND
  - LOW PRODUCTION RATE
  - LARGE NON-RECURRING COST

RELEVANCE AND BACKGROUND

(PAGE 2)

- MORE STARTS AND LESS PRODUCTION IN MILITARY
- EXTREMELY HIGH RISK TO RECOUP INVESTMENT IN COMMERCIAL
- INTERNATIONAL COLLABORATION MUST FOR FUTURE COMMERCIAL DEVELOPMENT
- LOW FUEL PRICES TOOK AWAY ADVANTAGE OF LIGHT WEIGHT COMPOSITES
- YESTERYEARS SLOGAN, "WEIGHT SAVINGS" NOW REPLACED BY , "COST SAVINGS"

HISTORICAL DEVELOPMENT OF COMPOSITE FABRICATION TECHNOLOGY

(PAGE 1)

- INTRODUCTION OF BORON, THE BIRTH OF ADVANCED COMPOSITE TECHNOLOGY
- BORON LIMITED FABRICATION TECHNOLOGY
  - HIGH COST OF BORON FILAMENT
  - LARGE BEND RADIUS
  - HIGH COST OF DIAMOND TOOLS
  - ONLY IN 3″ TAPE (NO FABRIC)
- FABRICATION TECHNOLOGY FOR BORON
  - HAND LAYUP THE MAIN METHOD
  - VERY SIMPLE HAND HELD TOOLS
  - CRUDE ATL MACHINE ONLY FOR R&D

HISTORICAL DEVELOPMENT OF COMPOSITE FABRICATION TECHNOLOGY
(PAGE 2)

- INTRODUCTION OF CARBON & ARAMID LEAD BREAKTHROUGH IN FABRICATION TECHNOLOGY
- ADVANTAGES OF CARBON OVER BORON
  - EXTREMELY SMALL BEND RADIUS
  - HIGH STRENGTH STEEL TOOLS
  - POTENTIAL FOR LOW COST ($10 VS $90)
  - VARIETY OF STRENGTH & STIFFNESS
- FABRICATION TECHNOLOGY FOR CARBON
  - FABRIC INCREASED SPEED OF LAYUP
  - TAPES CAME IN 3, 6, 12, 24, 60'' WIDTHS
  - COMPUTER CONTROLLED ATL IN PRODUCTION

HISTORICAL DEVELOPMENT OF COMPOSITE FABRICATION TECHNOLOGY
(PAGE 3)

- FABRICATION TECHNOLOGY FOR CARBON
  - AUTOMATIC CUTTING MACHINE INTRODUCED
  - CO-CURED TECHNOLOGY DEVELOPED
  - GRAPHITE TOOLS AVAILABLE
  - FILAMENT WINDING & BRADING POSSIBLE
  - PULTRUSION POSSIBLE
  - FORMING, MOLDING, STAMPING, ETC. OK
  - STITCHING OF PREFORMS & PREPLIES OK
  - 3-D WEAVING NOW POSSIBLE
- OIL SHOCKS OF 1973 AND 1979 LEAD TO SLOGAN "REDUCED WEIGHT FOR REDUCED FUEL COST"

HISTORICAL DEVELOPMENT OF COMPOSITE FABRICATION TECHNOLOGY
(PAGE 4)

- AIRCRAFT EFFICIENT ENGINE (ACEE) PROGRAM INTRODUCED TO SAVE FUEL
- INDIVIDUALLY TAILOR-MADE PLIES TO SAVE A MERE OUNCE AT SUBSTANTIAL COST
- FEAR OF INCREASED FUEL COST NEVER CAME INSTEAD FUEL COST DROPPED
- ACEE PROGRAM FUNDING DISAPPEARED
- FROM WEIGHT SAVINGS TO COST SAVINGS
- FROM ACEE TO ADVANCED COMPOSITE TECHNOLOGY
- FROM MILITARY TO COMMERCIAL

HISTORICAL DEVELOPMENT IN JAPAN
(PAGE 1)

- JAPAN FOLLOWED SIMILAR DEVELOPMENT
- LESS EMPHASIS ON AEROSPACE

CARBON FIBER USAGE IN 1989 UNIT: TONS

APPLICATION	USA	JAPAN	EUROPE	ASIA
AEROSPACE	1550	40	530	0
SPORTING	400	720	270	1080
INDUSTRIAL	550	350	300	10

- MORE EMPHASIS ON SPORTING GOODS

HISTORICAL DEVELOPMENT IN JAPAN
(PAGE 2)

- MORE EMPHASIS ON CARBON FIBER PRODUCTION

CARBON FIBER PRODUCTION CAPABILITY
(PAN & PITCH)

USA	JAPAN	EUROPE	ASIA
4560	6879	1150	250

IN 1991 UNIT: TONS

- TEXTILE INDUSTRY TOOK INITIATIVE IN JAPAN
- CHEMICAL INDUSTRY TOOK INITIATIVE IN USA

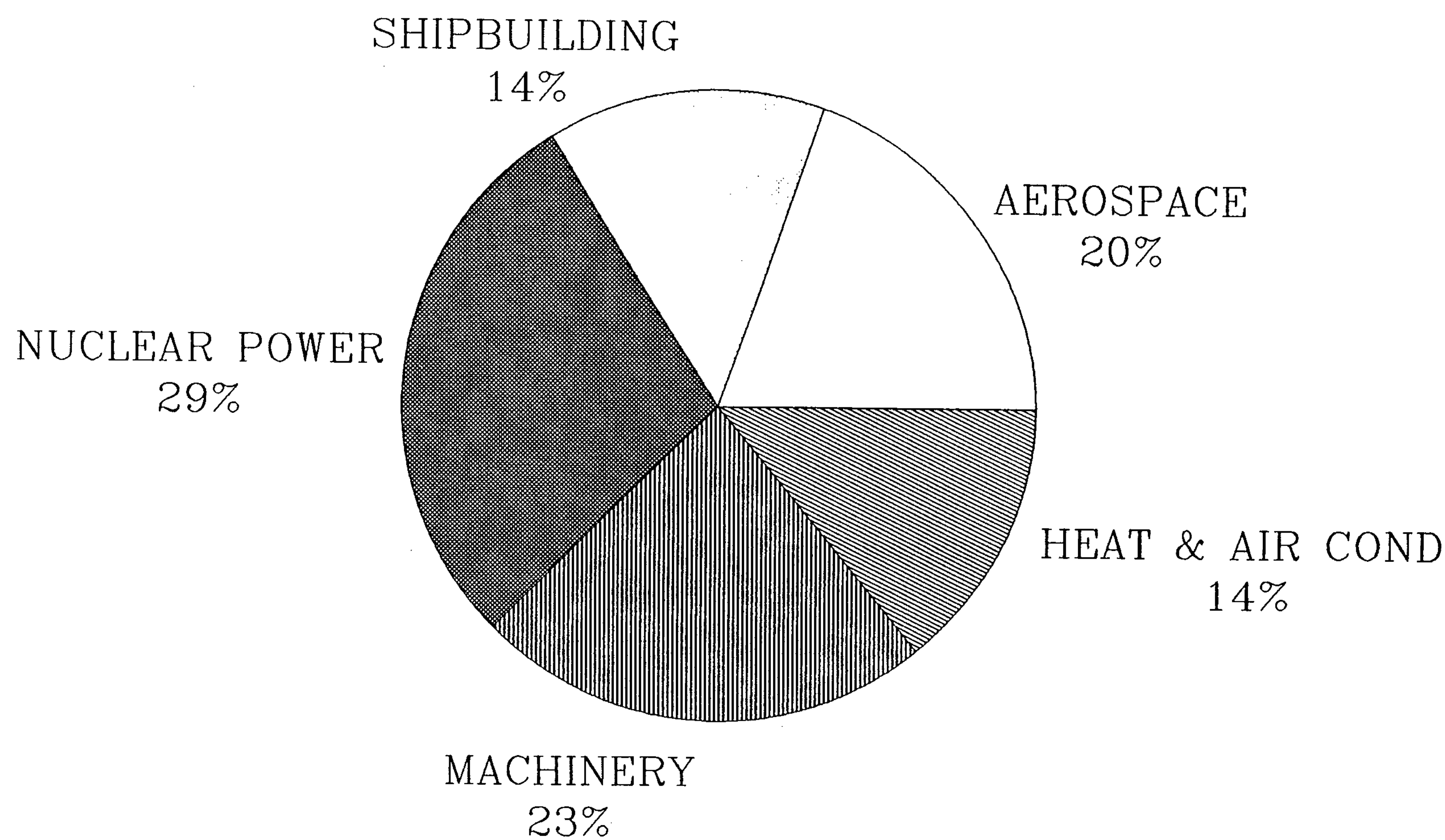
JAPANESE AEROSPACE INDUSTRY

- SMALL COMPARED TO U.S. AEROSPACE INDUSTRY, 1/10 THE SIZE OF U.S.; 1/3 OF U.K.
- EXPORT/IMPORT RATIO

USA	JAPAN	FRANCE	U.K.	CANADA
3.3/1	1/6	2.5/1	1.28/1	1/1.75

- LARGE VOLUME OF IMPORTS (MOSTLY FROM USA)
- ADVANCED PRODUCTION TECHNOLOGY, RELIABLE DELIVERY, HI QUALITY MADE JAPAN COMPETITIVE
- AEROSPACE ACCOUNTS ONLY 20% OF TOTAL SALES FOR MAJOR AIRCRAFT RELATED HEAVY INDUSTRIES

TYPICAL JAPANESE "HEAVY INDUSTRY" COMPANY



percentage of sales

JAPANESE AEROSPACE INDUSTRY'S HEAVY RELIANCE ON DEFENSE SPENDING

MILITARY/CIVIL DEMAND (BIL. YEN)

YEAR	TOTAL OUTPUT (A)	GROWTH RATE	MILITARY (B)	CIVIL	RATIO (B/A)
1988	661	1.2%	523	138	79.1%
1989	731	10.5%	558	173	76.3%
1990	802	9.7%	601	201	74.9%
1991	851	6.2%	639	212	75.1%
1992	800	(6.0%)	N/A	N/A	N/A

MITI

- U.S. RELIANCE ON DEFENSE SPENDING, 56%

CURRENT EVENTS AFFECTING COMPOSITE FABRICATION TECHNOLOGY

(PAGE 1)

- FALL OF BERLIN WALL & COLLAPSE OF USSR
- END OF COLD WAR & BURST OF BUBBLE ECONOMY

<u>CAUSING</u>

- DRASTIC CUTBACKS IN DEFENSE SPENDING
- DEEP AND LONG RECESSION WORLD WIDE
- AIRLINE INDUSTRY SHOWED UNPRECEDENTED LOSS

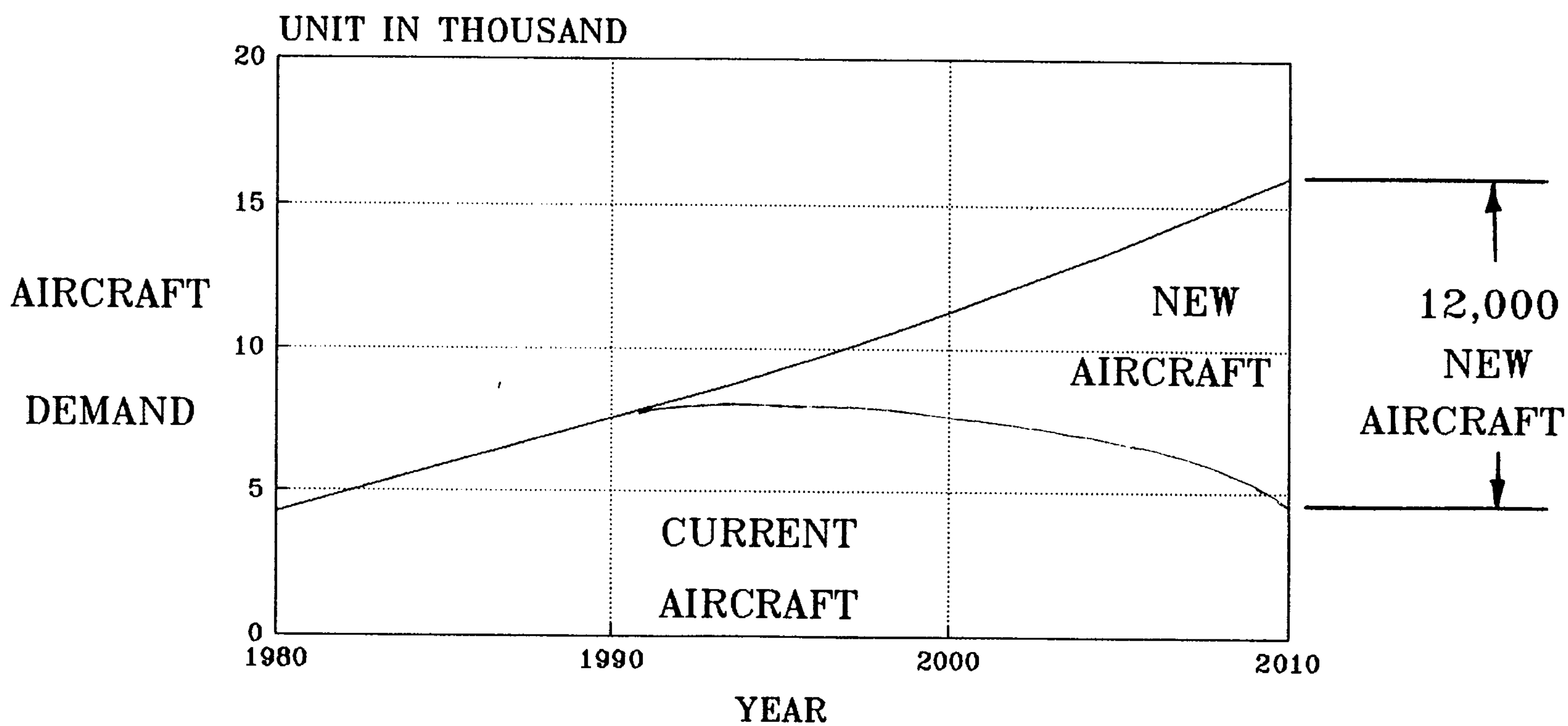
CURRENT EVENTS AFFECTING COMPOSITE FABRICATION TECHNOLOGY

- ELIMINATION OR REDUCTION IN SCOPE OF MILITARY AIRCRAFT OF HIGH COMPOSITE CONTENT (USA)

  A–12 B–1 B–2 ATF C–17 OV–22

- NEW CONTRACTS AND NEW AIRCRAFT PROGRAMS FEW AND FAR APART (MILITARY & COMMERCIAL)
- OVER CAPACITY AND THROAT CUTTING PRICE WAR REDUCING PROFIT AND R&D FUNDING
- AIRLINES ORDERING LESS NEW AIRPLANES WITH COMPOSITE PARTS AND REFURBISHING OLD PLANES

COMMERCIAL AIRCRAFT DEMAND BY YEAR 2010



- 1/3 TO REPLACE AGING AIRCRAFT
- 2/3 FOR FUTURE GROWTH
- $900 BILLION MARKET

Current Status of U.S. and Japanese Fabrication Technology and Applications

Distribution of Composite Structures Technology

- Little Basic Research. Mostly Applied Research From Basics Done in Europe and the U.S.
- MITI Sponsored Projects Done as a Research Company Made Up of Many Company Collaborators
- New MITI Projects in Aerospace Must Involve a Foreign Member
- Companies Like Nikkiso and JAMCO do Independent Applied Research. Unique Products and Solutions.

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1A

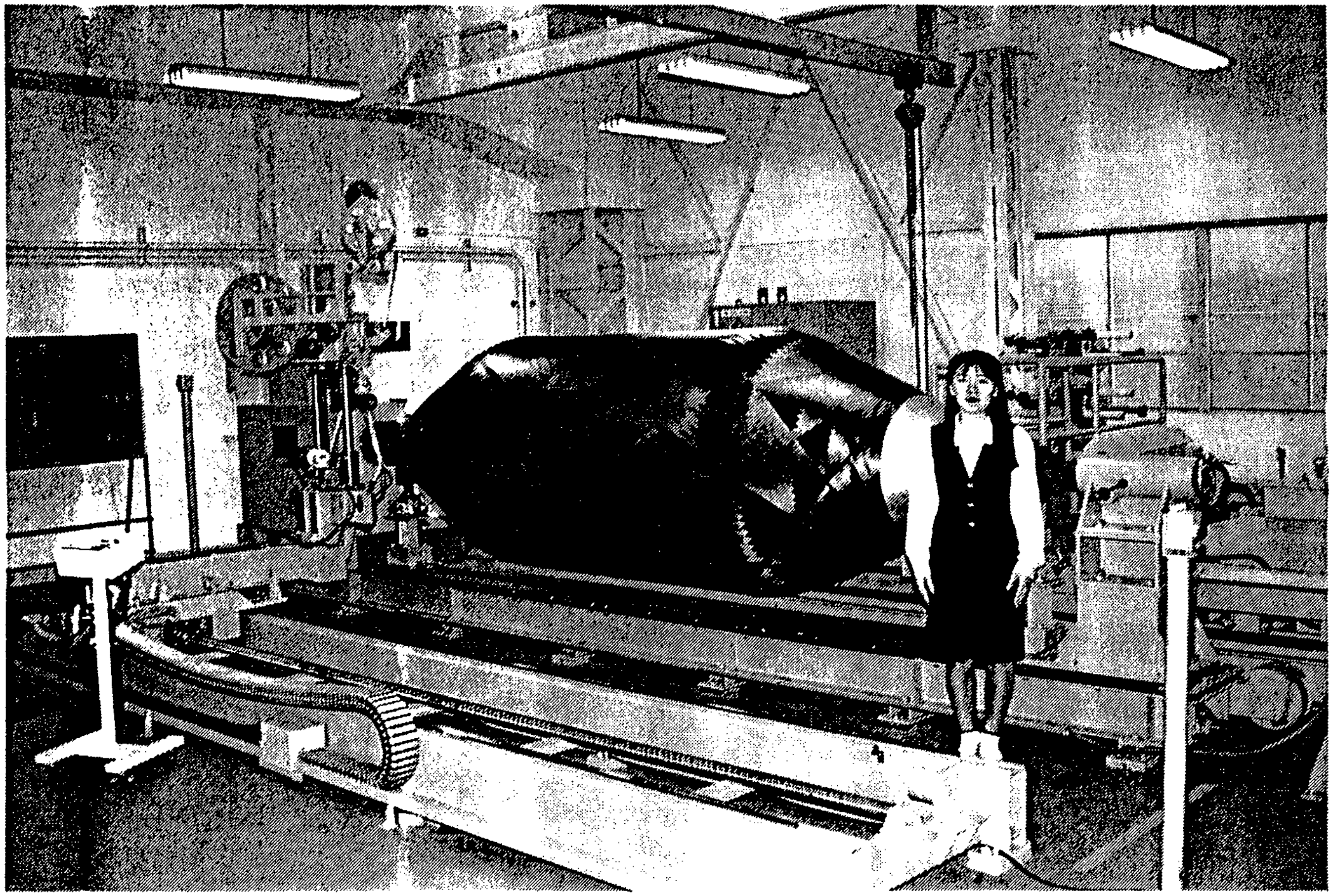


FIG. 6.

PICTURE OF THE TAPE WINDING DEVICE

60

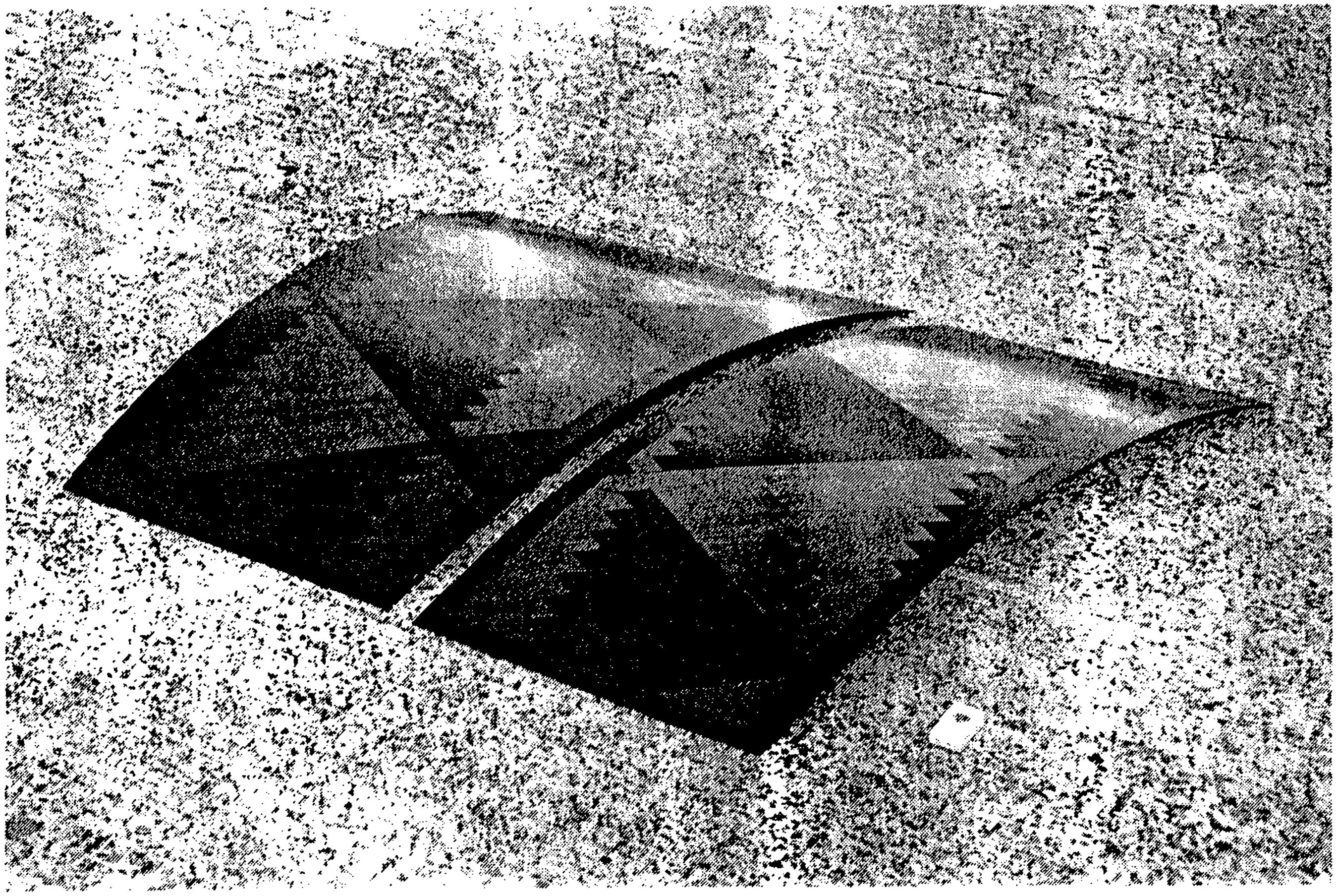
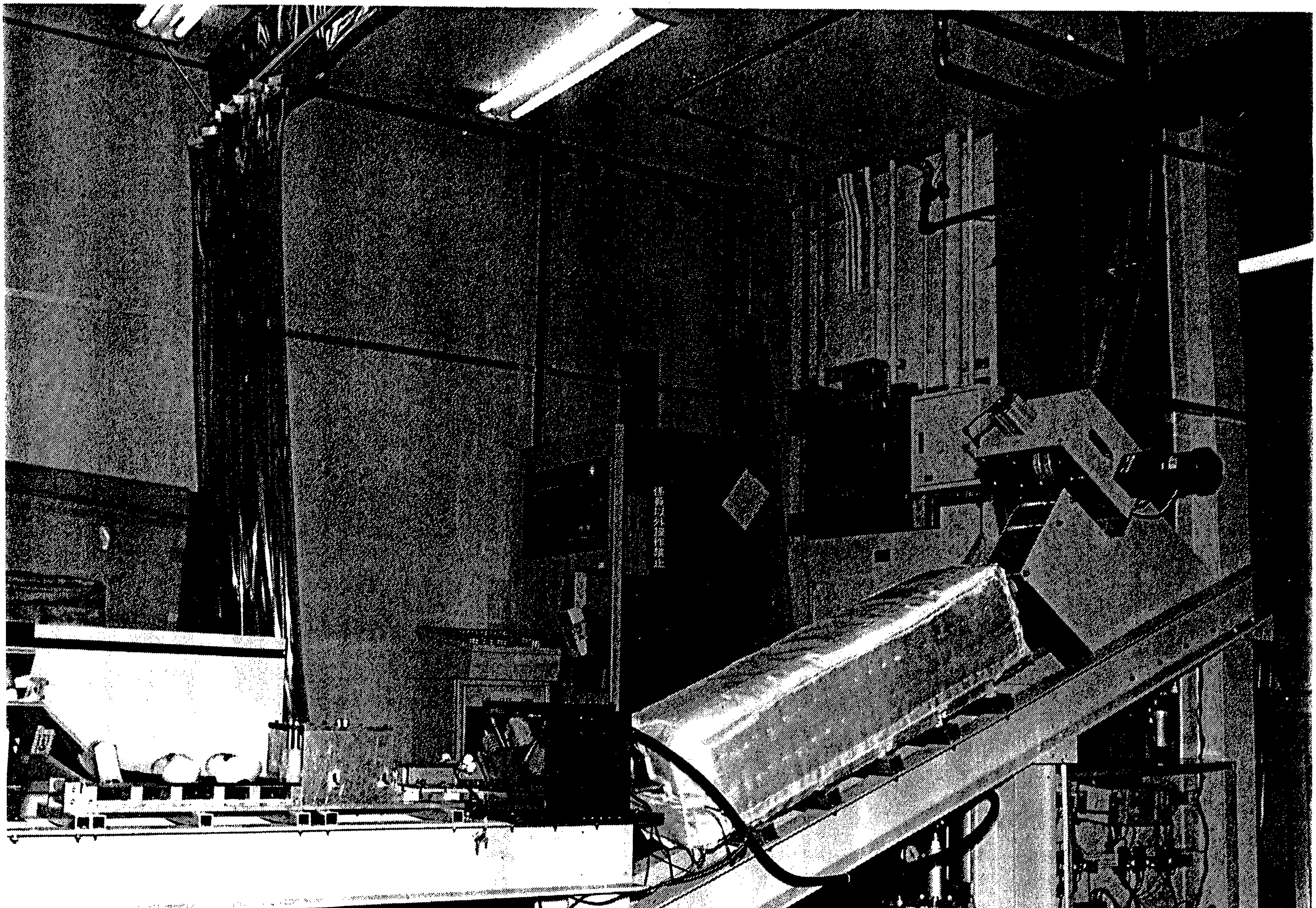
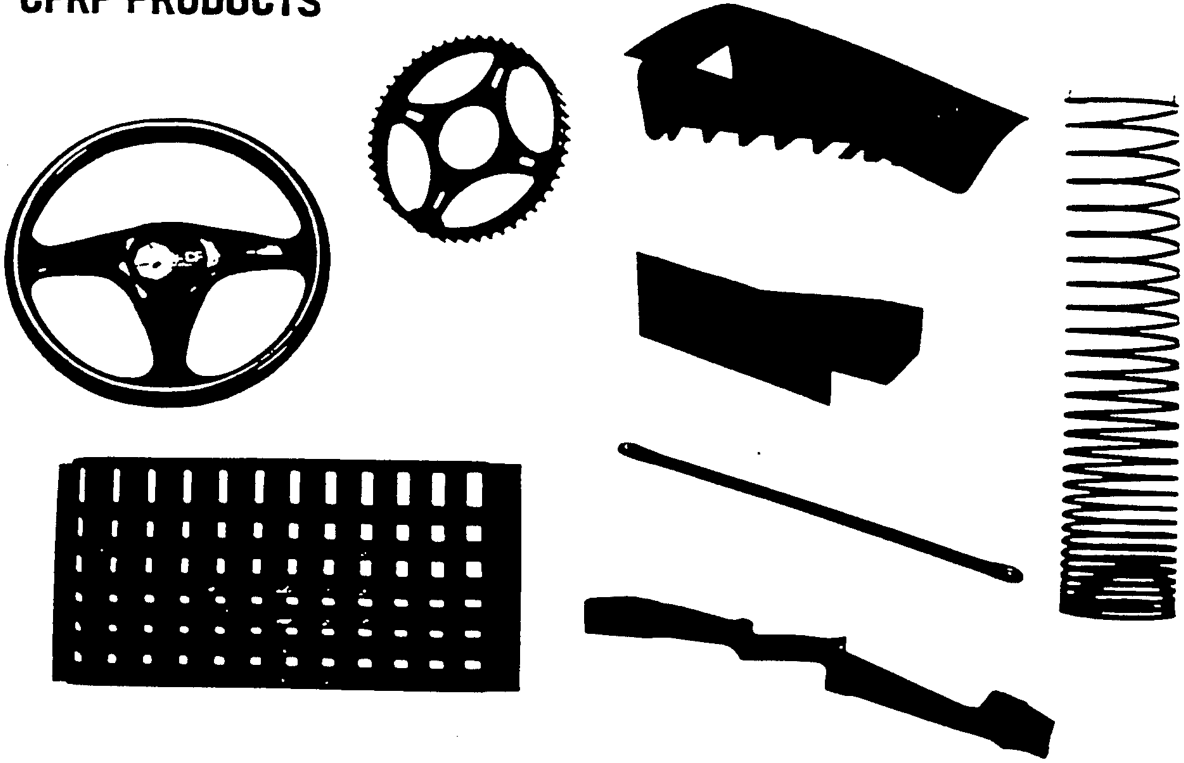


FIG. 7.

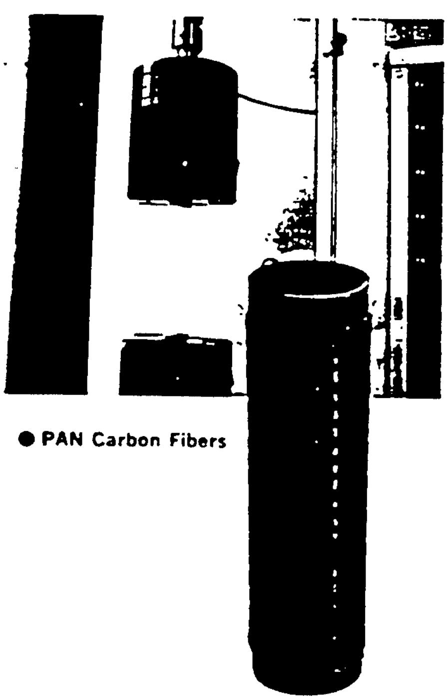
PICTURE OF FULL SCALE PANEL



CFRP PRODUCTS



DEVELOPMENT'S PRODUCTS



● PAN Carbon Fibers

● Graphite Whisker
(GRASKER®)

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Major Differences in Japan Vs. U.S. Approach to Applied Research

- Japan Funds for Five to Ten Year Projects With Well Thought Out Objectives and Reasonable Expectations
  - Broad Application
  - Sufficient Allocation of Time and Funding

- U.S. Funds Reviewed Annually on Three to Five Year Projects With Unreasonable Expectations
  - Promotes Overstatement of Results
  - Failing Forward Not Tolerated
  - Promising Technologies Dropped Before a Thorough Conclusion is Reached
  - Successful Technologies Are Not Transitioned into Production
    - Insufficient Data Published Intentionally Due to Competition
    - Project Overstated Conclusion and Much Work Remains

DRG3-2/1/93

Based on the Trip and Literature, How Does Each Company Visited Fit in the Composites Picture?

- The Evaluation is Qualitative and is an Opinion.
- Three Heavy Industries Have Equal Focus, with Fuji Very Involved in Production. Fuji Methods Evolved from U.S. Requirements.
- Mitsubishi Electric is Very Involved in Applied Manufacturing Research and Low Rate Space Structure.
- National Aerospace Laboratory (NAL) is Primarily an Evaluation Center for Things Made at the Heavy Industries.

Composite Focus by Institution

	Basic Research	Applied Research	Composite Evaluation	Space Structure	Military Composite	Commercial Aircraft	Composite Interiors	% US Customers
Kawasaki H.I.		◒	◒	○	●	◒		◔
Mitsubishi H.I.		●	◒	○	◕	◔		◒
Fuji H.I.		◔	◒		◒	●		◕
Nikkiso	◒	●	◒			◕		◒
JAMCO		◔	○			●	●	●
U of Tokyo	○	◔	◒					
NAL		◒	●					
Mitsubishi Electric		●	◔	●				

● High

○ Low

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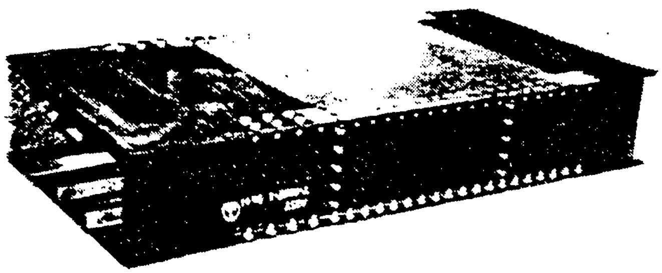
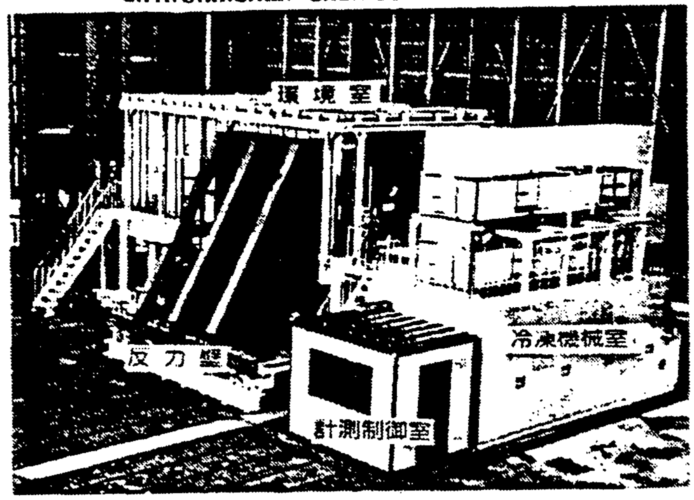


炭素／熱可塑複合材翼構造モデル
の研究開発および関連基礎研究

R & D of CF Thermoplastic Wing Box Model and Related Basic Research

H. 大型環境付与装置
Environmental Chamber for Structural Tests.



Main Spec.

Size : 9×5×3m
Temp. : −70°C～200°C
Range 350°C on Object Surface
Humidity : 95%RH

C. 十字型二軸疲労試験機 Bi-Axial Testing Machine of Cruciform Type

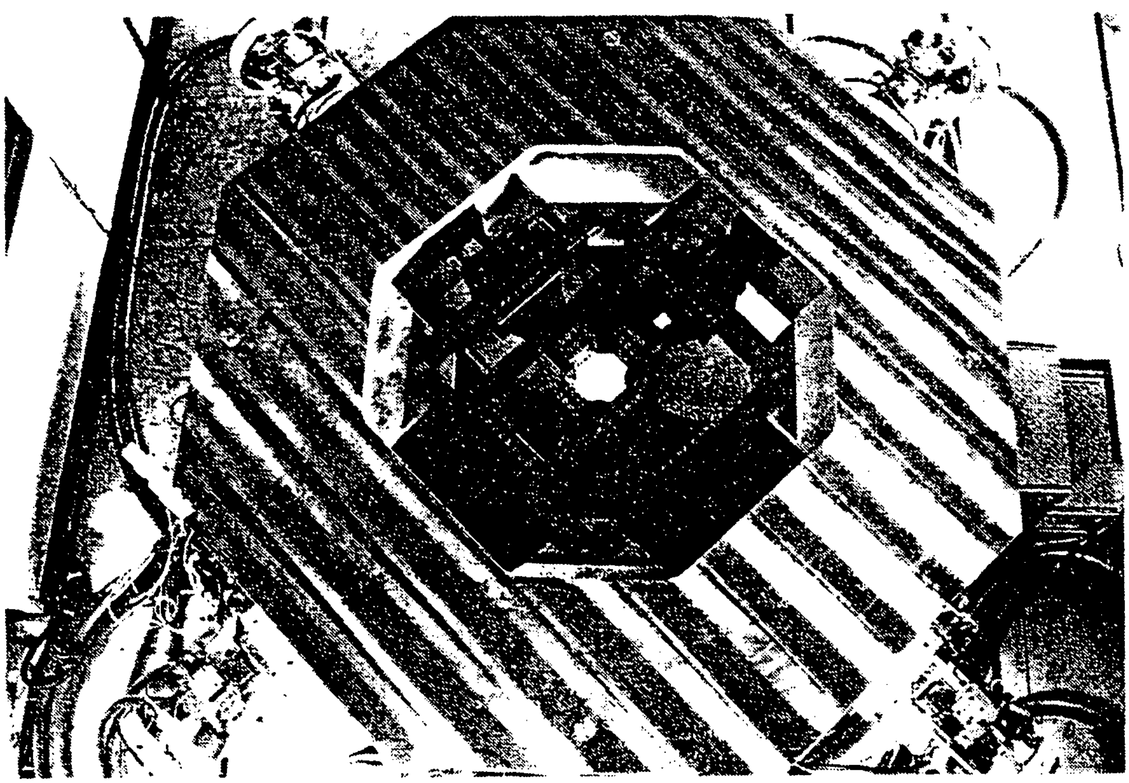


Figure NAL-1

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POSTBUCKLING DESIGN

ANALYSIS

POST BUCKLING DISPLACEMENT AND STRESS

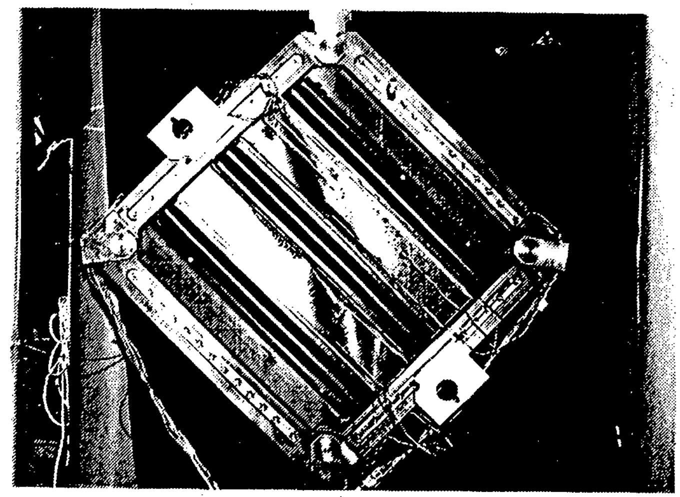
SKIN STIFFENER CO-CURED PORTION STRENGHT

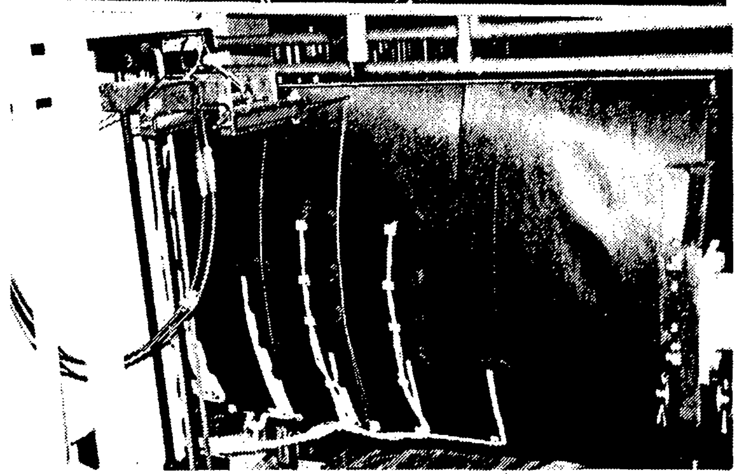
TEST

CO-CURED STIFFENED PANEL (BEAD, HAT, BLADE)

SKIN/FRAME/SPAR CO-CURED FUSELAGE PANEL MODEL

etc.





MHI

PAYLOAD ATTACH FITTING

MODEL: H-1 ROCKET ERS-1

TYPE: Integrated structure of Gr/Ep skin, stringers and ribs

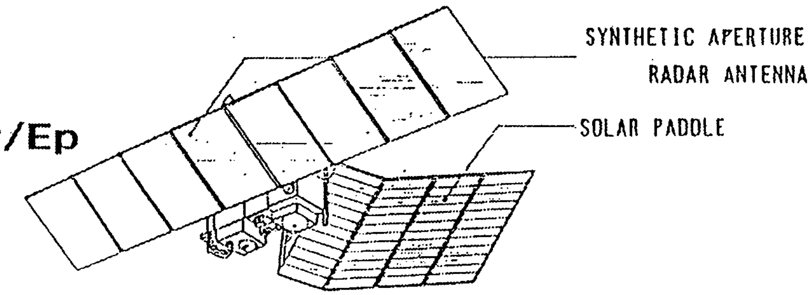
SIZE: 60"(DIA) × 16"(H)

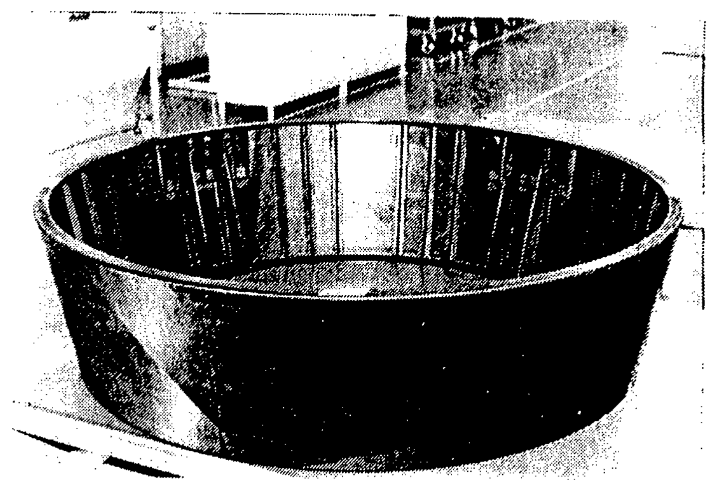
FAB. METHOD: Co-Curing Process
[Gr/Ep skin, stringers and ribs are all cured at one time]

TOOL: Machined invar tool

REMARKS:
NASDA contract in 1986

First launch was in Feb. 1990





MHI

PAYLOAD ATTACH FITTING

MODEL: H-2 ROCKET ETS-6

TYPE: Integrated structure of Gr/Ep skin, stringers and ribs

SIZE: 95"(DIA) × 12"(H)

FAB. METHOD: Co-Curing Process

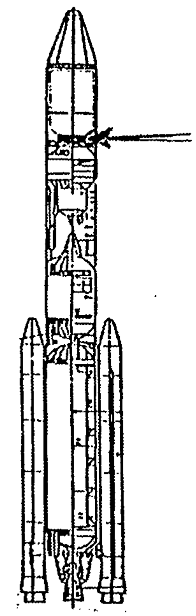
(Gr/Ep skin, stringers and ribs are all cured at one time)

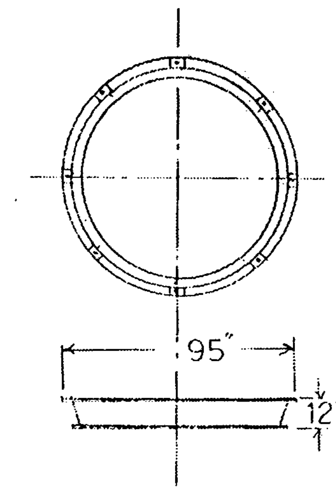
TOOL: Machined invar tool

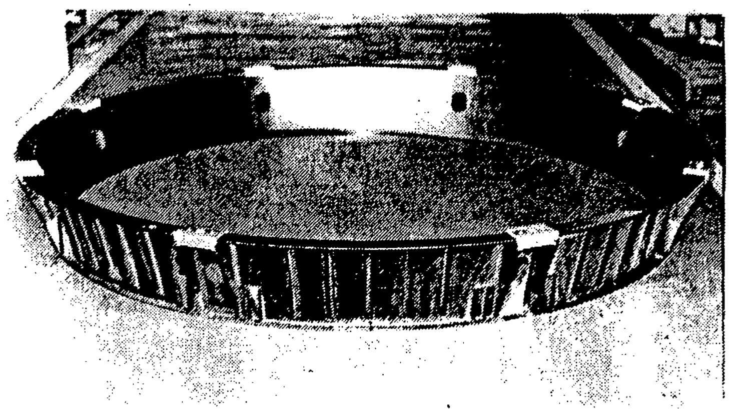
REMARKS:

NASDA contract in 1987

First launch will be in Feb. 1994







MHI

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TAIL CONE

MODEL: Douglas MD-11

TYPE: Bead stiffened skin panel

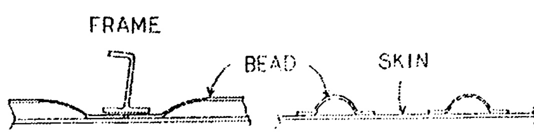
SIZE: 63"(W) × 71"(H)

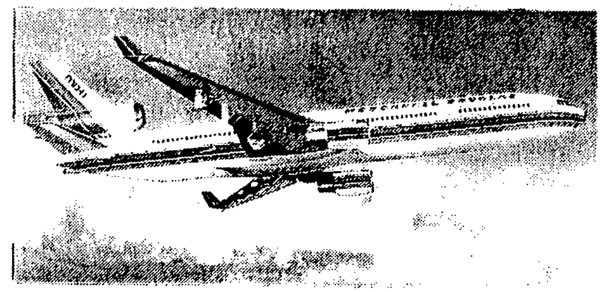
FAB. METHOD: Secondary Bond Process
(Gr/Ep skin, beads and frame are pre-cured then secondary bonded)

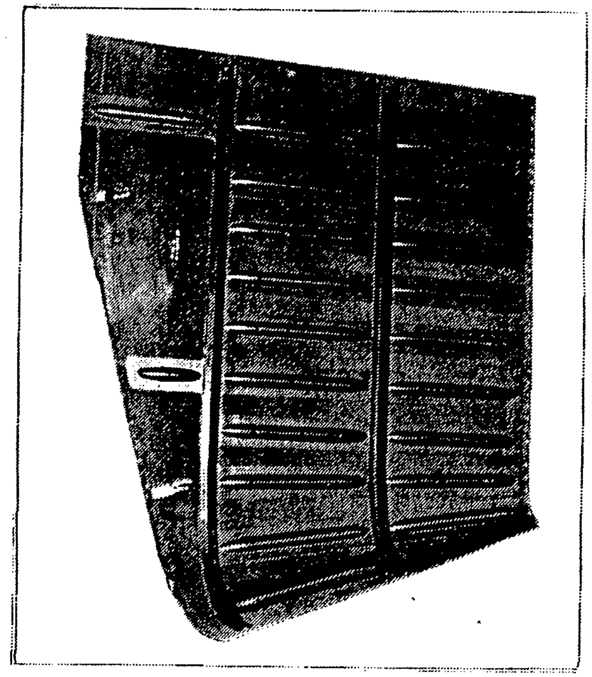
TOOL: Machined Invar tool

REMARKS:
Production has started in 1987

Design and FAA T/C are MHI's responsibility







MHI

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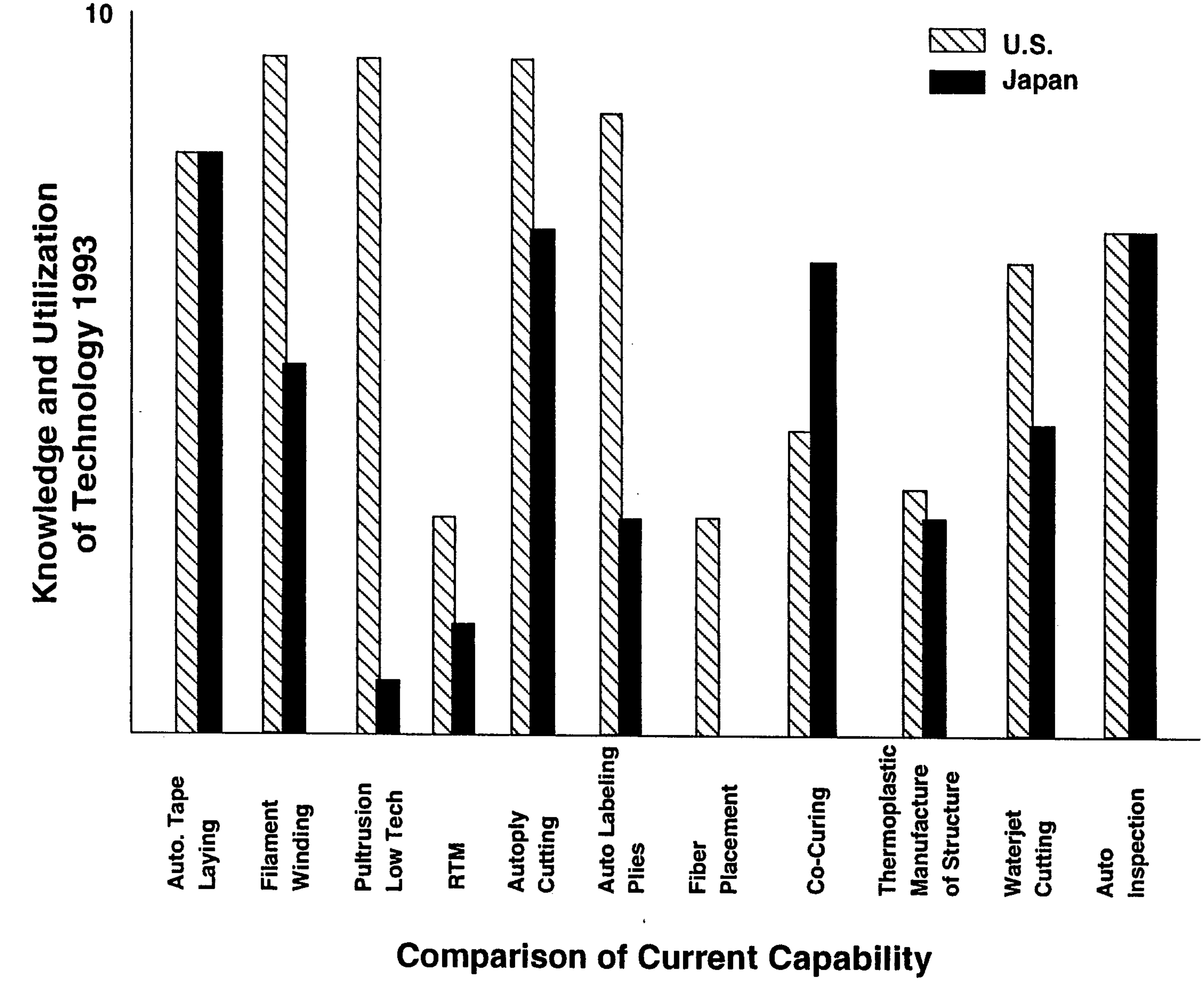
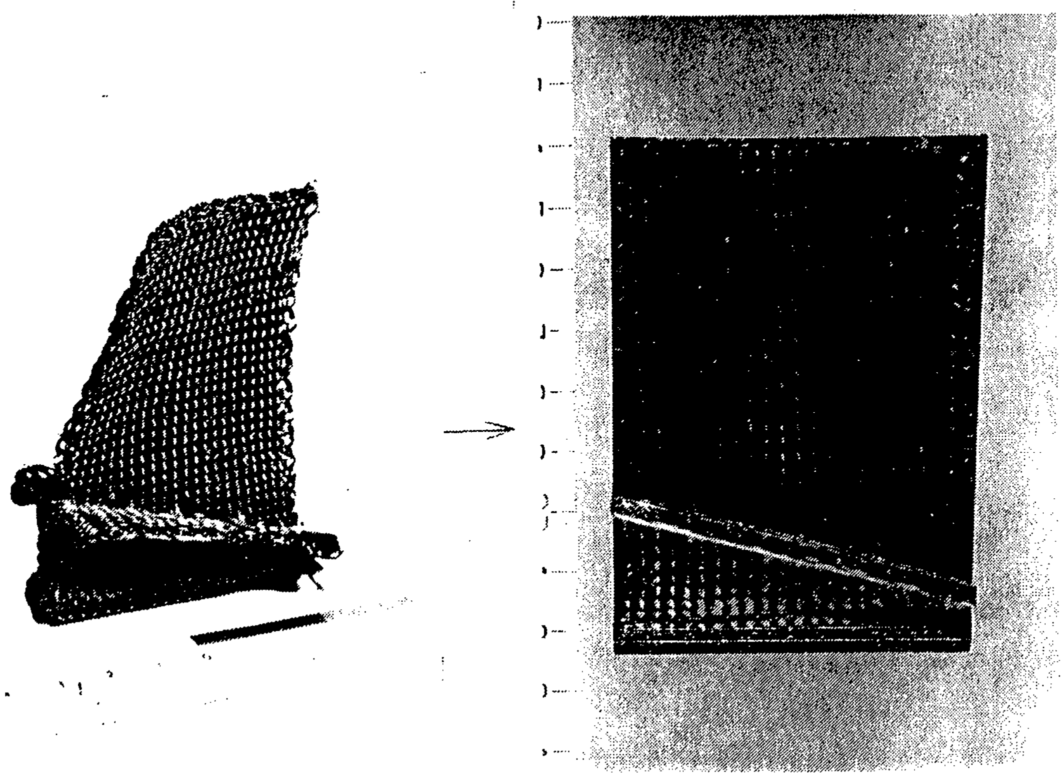

10
Knowledge and Utilization of Technology 1993
U.S.
Japan
Auto. Tape Laying
Filament Winding
Pultrusion Low Tech
RTM
Autoply Cutting
Auto Labeling Plies
Fiber Placement
Co-Curing
Thermoplastic Manufacture of Structure
Waterjet Cutting
Auto Inspection
Comparison of Current Capability

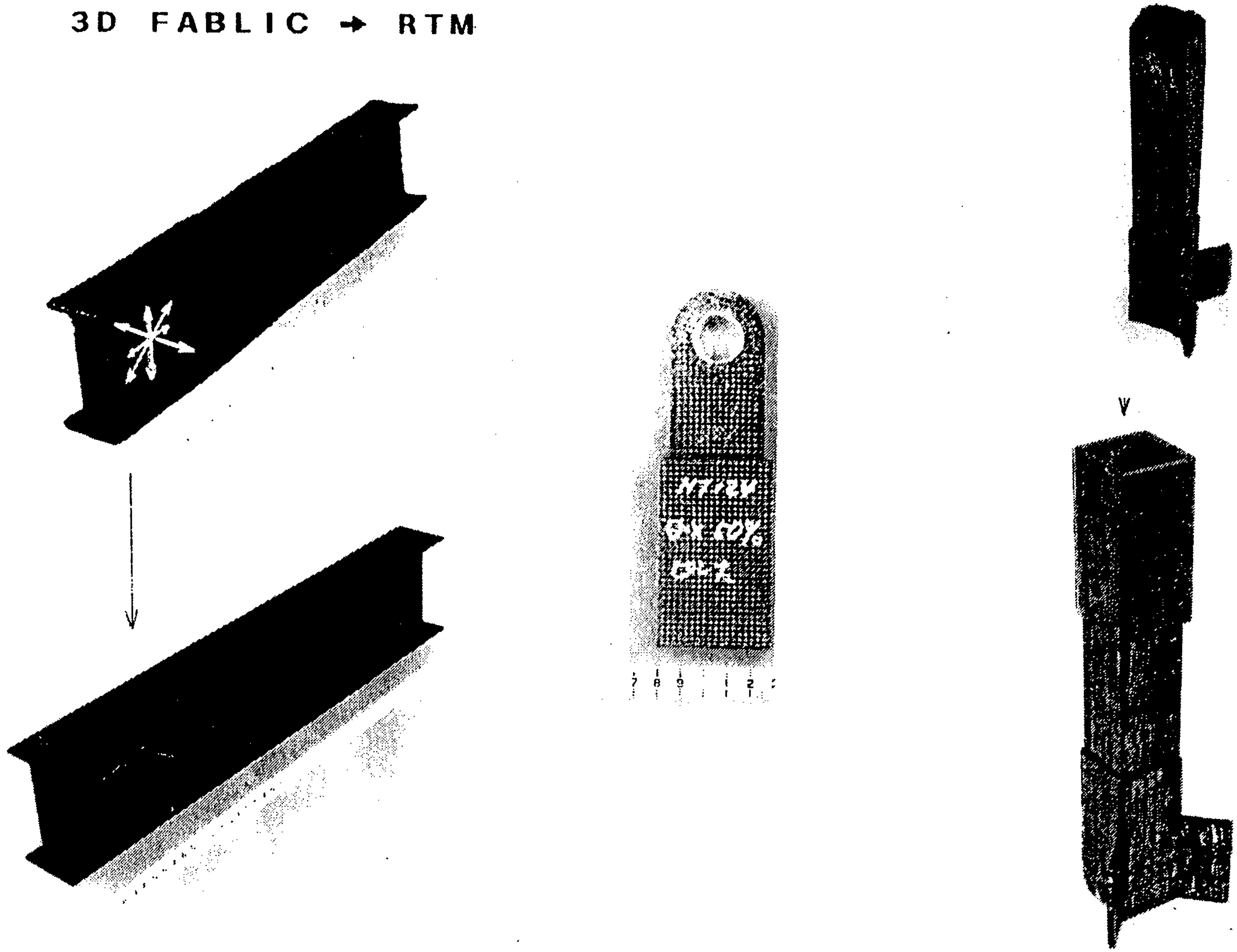
DRG6-2/1/93

3D FABLIC → RTM



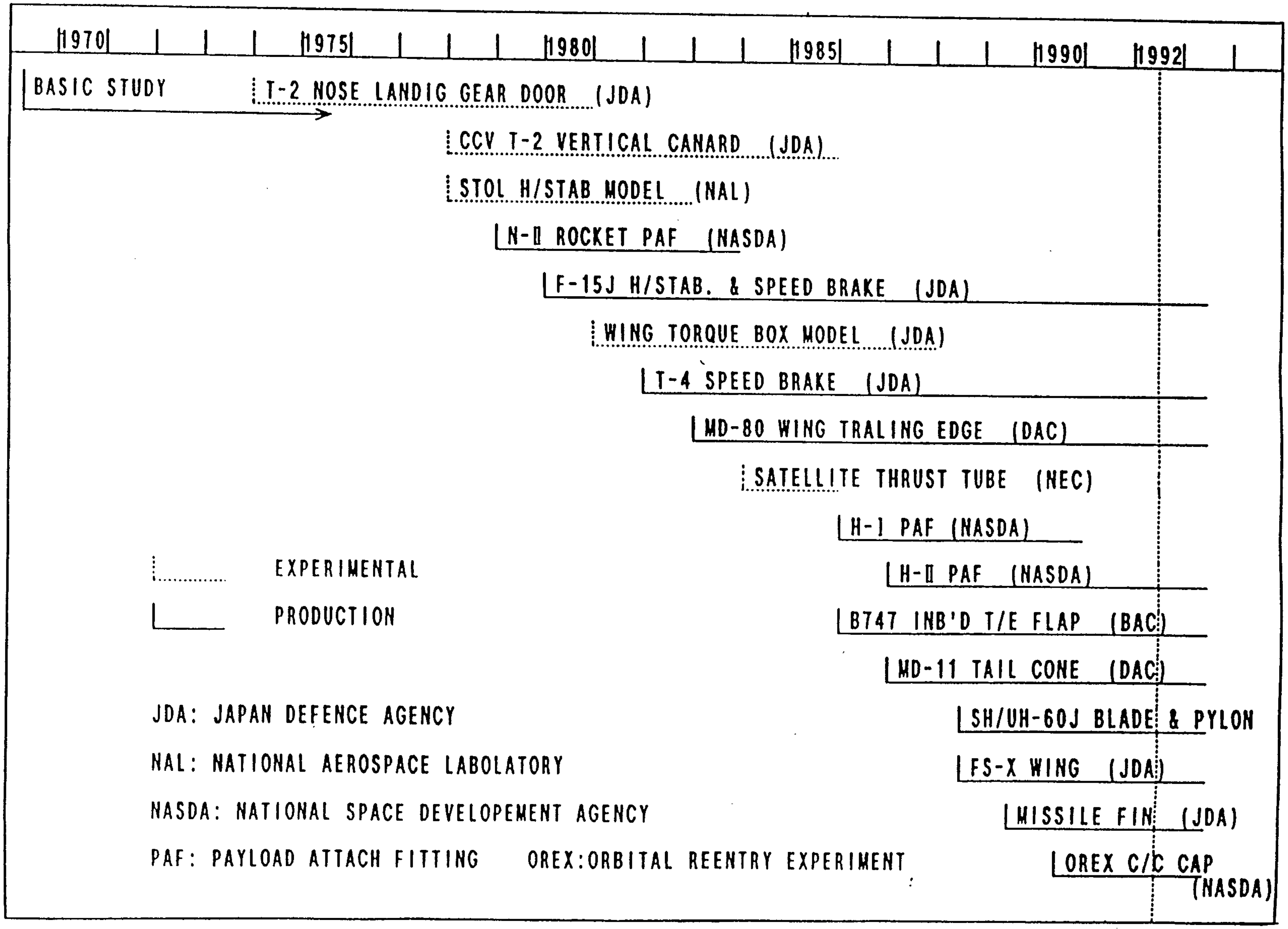
MHI

3D FABLIC → RTM



MHI

MAJOR COMPOSITE APLICATIONS



MHI

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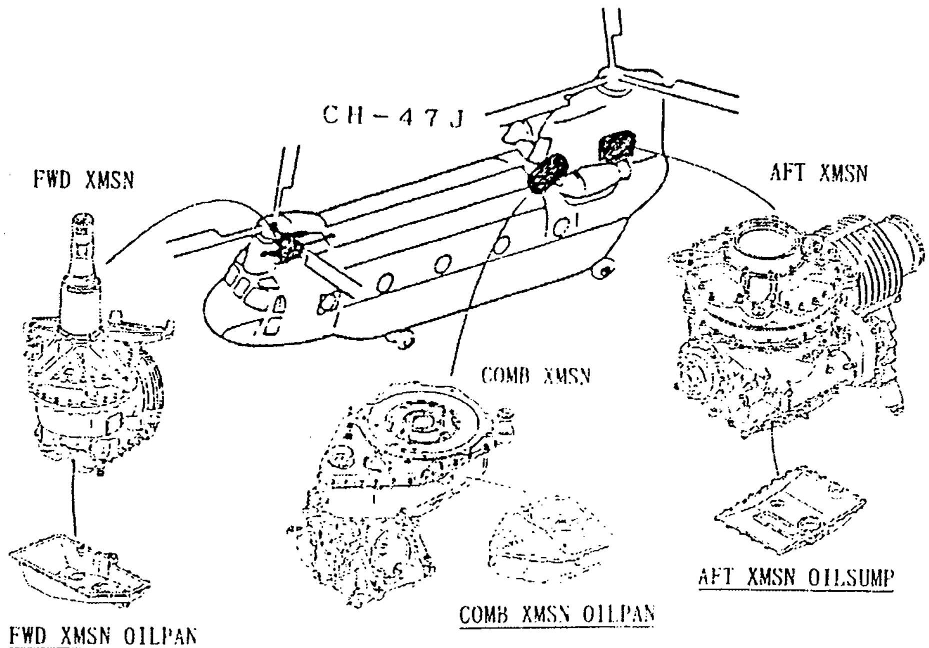
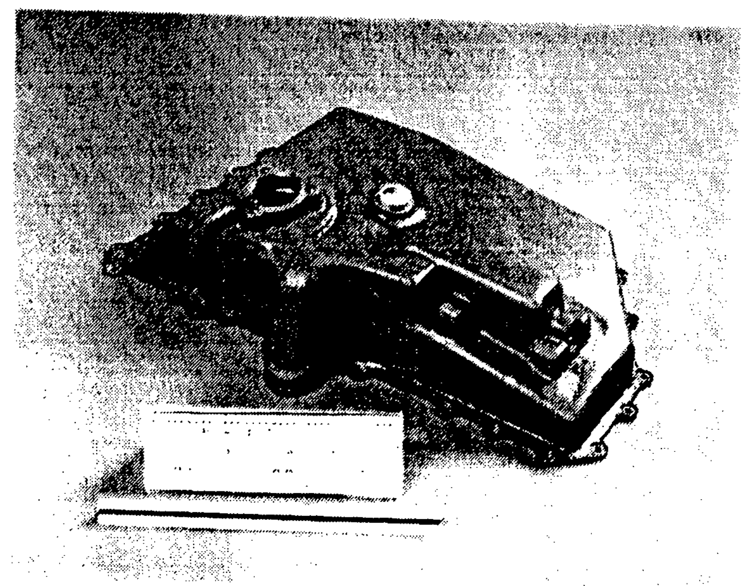
No.	Products		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Material and Remark
①	P2V-7 & P2J Radome	1959																GFRP/Glass Honeycomb First composite part
②	C-1 Ground Spoiler	1974																CFRP/Al Honeycomb First CFRP part (Flight evaluation test conducted)
③	B747SP Flap	1975																GFRP/Glass Honeycomb Co-cure molding process
④	BK117 Doors & Panels																	AFRP/Nomex Honeycomb ; Co-cure molding process, water jet cutting
⑤	P-3C Radome & Mad Boom																	GFRP/Glass Honeycomb Fabrication technique of large radome
⑥	F-15 Vertical Fin Torque Box & Rudder																	BFRP/Al Honeycomb NDI technique with ultrasonic facilities
⑦	T-4 Aileron, Rudder & Nose LDG Door																	CFRP/Nomex Honeycomb AFRP/Nomex Honeycomb
⑧	MD-80 Flap Hinge Fairing																	AFRP Laminate CFRP molding tool
⑨	B747 Outboard Flap																	GFRP/Nomex Honeycomb Molding process of long parts
⑩	CH-47 Transmission Oilpan																	AFRP Laminate ; Molding Process of Compicated parts and laser triming
⑪	FSX Fuselage Cover Panels & Main LDG Door											under development						CFRP Laminate (Co-cured), CFRP/Al Honeycomb Medium modulus, tough resin comp.
⑫	C-1 STOL Flap Trailing Edge																	GFRP/Glass Honeycomb Bismaleimide resin comp.

AFRP : Kevlar fiber reinforced plastic
BFRP : Boron fiber reinforced plastic
CFRP : Carbon fiber reinforced plastic
GFRP : Glass fiber reinforced plastic

Composite Products in KHI





Material : Kevlar/epoxy laminate (AFRP)
-Co-cure with metal inserts

Size : 3.5mmt × 0.4m × 0.7m

CH-47 Oilpan

Japan's Tooling Experience and Focus

- Currently All Common Systems in Use
  - Electroplated Nickel
  - Invar
  - Steel
  - Composite
  - Silicone Rubber
  - Reusable Silicone Rubber Contour Bags

- Future Tooling
  - Matched Metal-Controlled to Stops
  - Reusable Silicone With Integral Vacuum Manifolds
    - Vacuum Manifold Indexes Stringers and Frames to OML
    - Cap Height Controlled by the Manifold
  - Rubber for Pressure Application Working Against Carbon Slip Sheets for Location
  - Tooling for High Temperature Materials is not Focused; Ceramic, Two Sheet Aluminum Diaphram

Observed Largest Potential For Cost Savings Exclusively Japanese

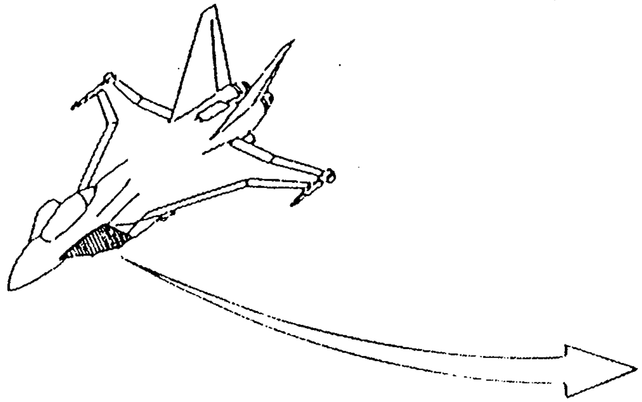
- Maximum Use of Cocure Through the Utilization of Complex Cure Tooling
  - Part Count Reduced by 50%
  - Fasteners Reduced by 2/3
  - Assembly Time Reduced by 50%

- All Subcomponents Hot Debulked and Accepted by Ultrasonic Inspection Prior to Component Cure
  - Building a History to Justify Reduced or Eliminated Inspection
  - Process Fully Characterized and Critical Parameters Identified

- Automation of Stiffeners and Structural Members
  - Slow Pultrusion Combined With Press Molding
    - One Inch Per Minute (Cured)
  - Slow Prepreg Winding of Thin Wall Tubular at 3 Ft/Hr (Cured)
  - Automated Forming of Blade Stiffeners From Tape Layed Broadgoods (Uncured)

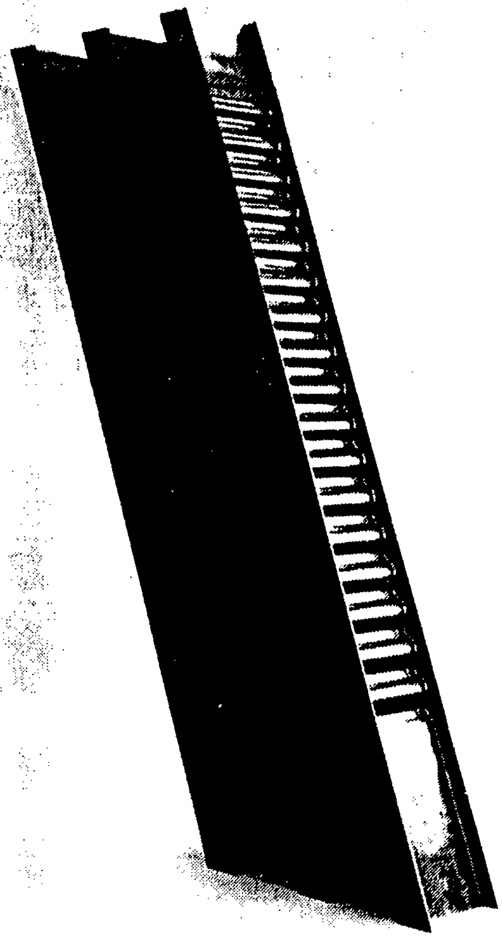
Observed Largest Potential For Cost Savings Exclusively Japanese (continued)

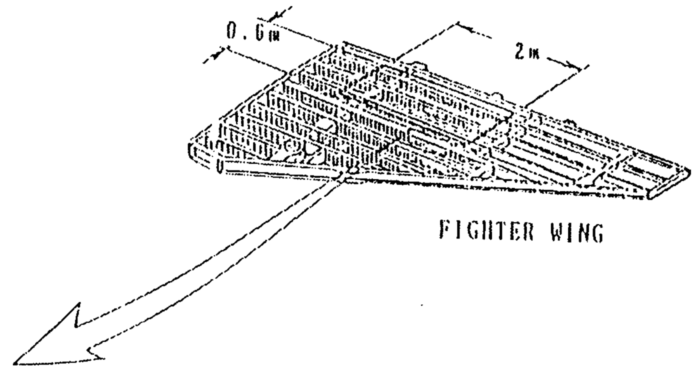
- Success with RTM
  - Attacking the Textile Cost
  - Complete Survey of World Status on Weaving Technology
  - Cherry Picked The Processes
  - Focus is on Low Cost Preforms Through Automation and Flexible Machines



- ◆ WEIGHT REDUCTION
- ◆ COST REDUCTION
- · AUTO TAPE LAYING
- · DRILLED BY ROBOT

COCURED CANARD BOX STRUCTURE





FIGHTER WING

MATERIAL

HIGH STRAIN GRAPHITE/EPOXY : SKINS, SPARS, RIBS

RESULTS

- ESTABLISHED FABRICATION METHOD OF SINE WAVE SPAR AND INTEGRAL STRUCTURE
- OBTAINED STRENGTH DATA OF SINE WAVE SPAR
- CONDUCTED STIFFNESS TEST OF BOX BEAM

RESEARCH PROGRAM OF SINE WAVE SPAR AND BOX BEAM

WING TORQUE BOX

MODEL: New Fighter Program

TYPE: Integrated structure of Gr/Ep skin, multi-spars and ribs

SIZE: 160"(L) × 80"(W)

FAB. METHOD: Co-Curing Process

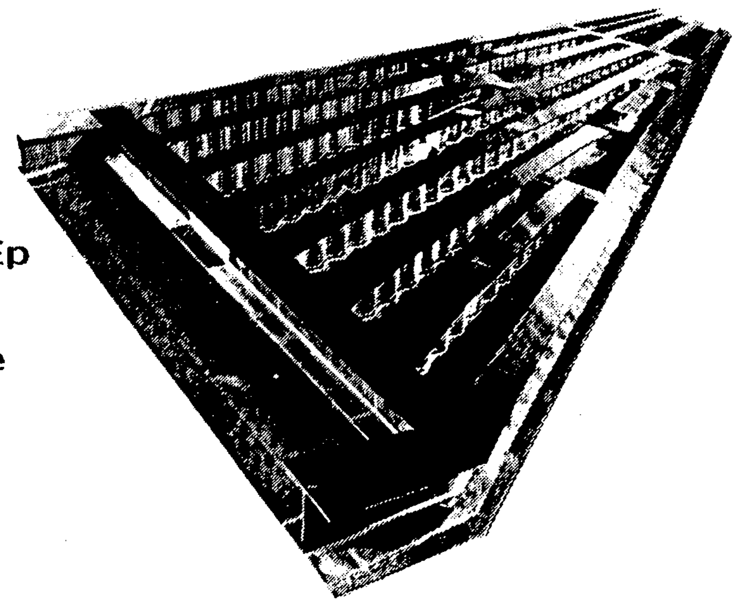
Gr/Ep skin, spars and ribs are all cured at one time

TOOL: Combination of steel and Gr/Ep

REMARKS:

Successfully static and fatigue load tested in 1987

JDA contract in 1985



MHI

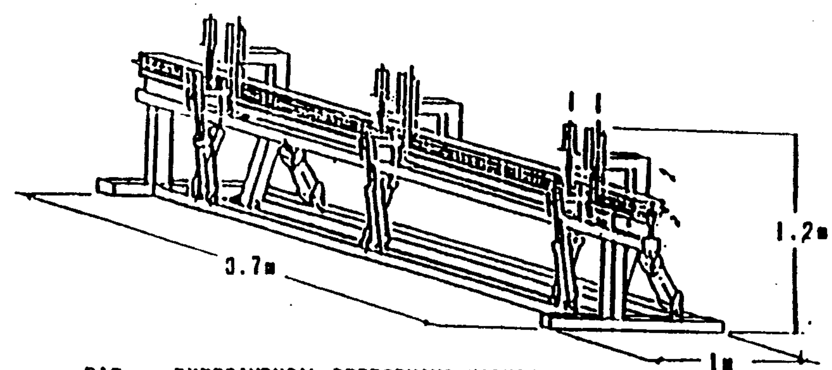
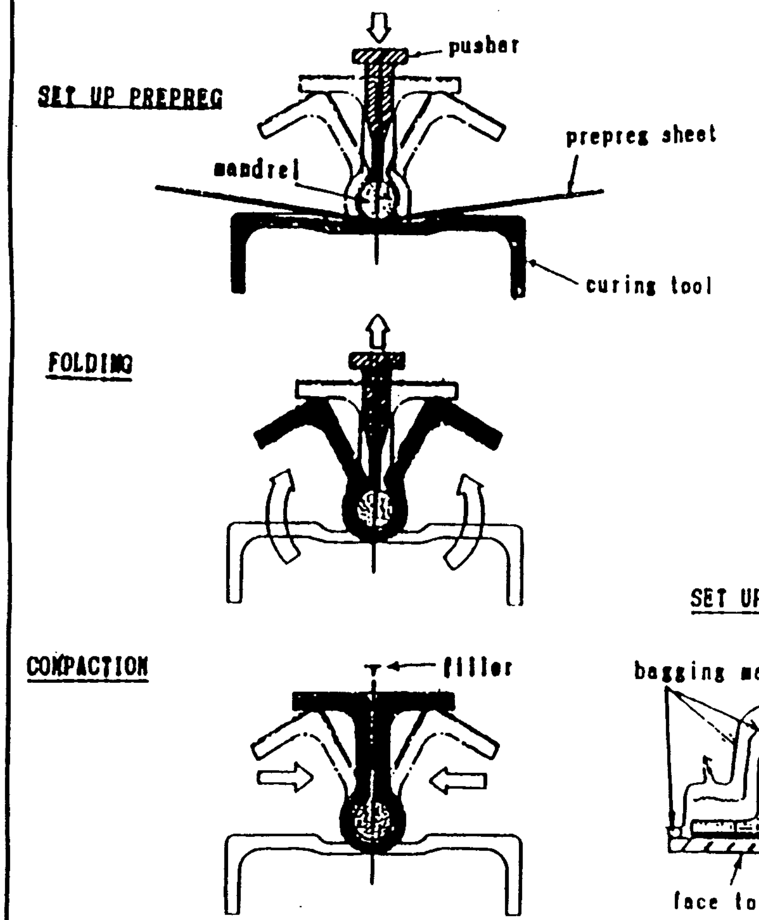
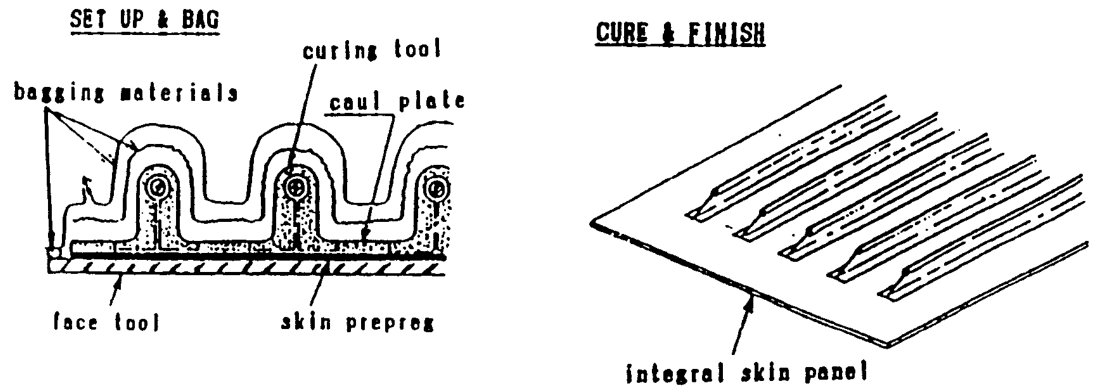


FIG. EXPERIMENTAL PREFORMING MACHINE FOR Ω-STRINGER

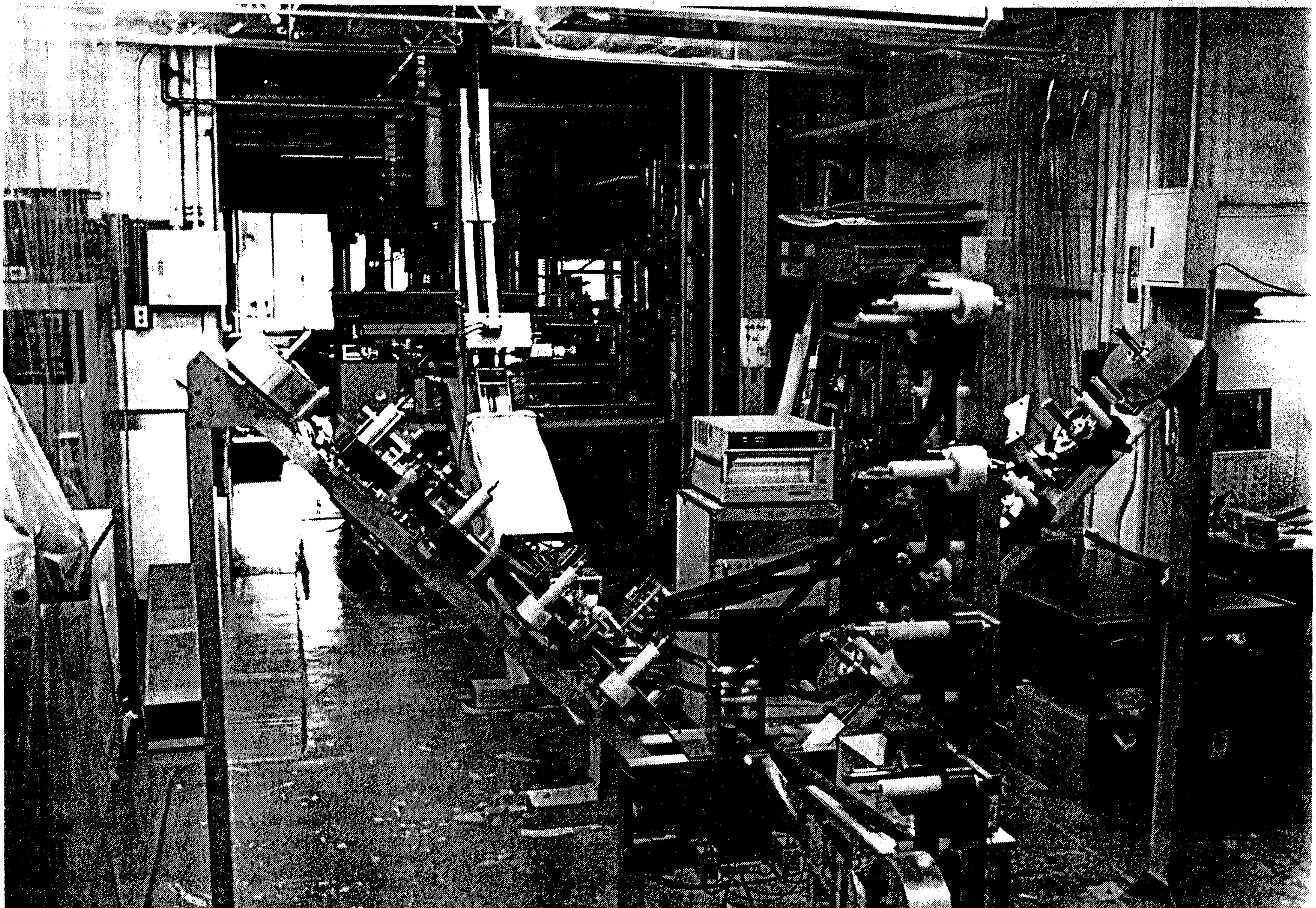




FOLDING PROCESS OF Ω-STRINGER

Projection of Japan's Future in Composite

- Dependent on the World Aerospace Market. Little Domestic Opportunity for Production
- Focused Applied Research Will Produce Lower Cost Composite Assemblies
  - Unique Advantage to Apply Complex Tools and Processes to the Bond Shop
- Thermoplastic and RTM Structures May be Cost Effective in Japan Before the U.S.
- Automation May be in the Form of Slow, Reliable Low Man Loaded Machines

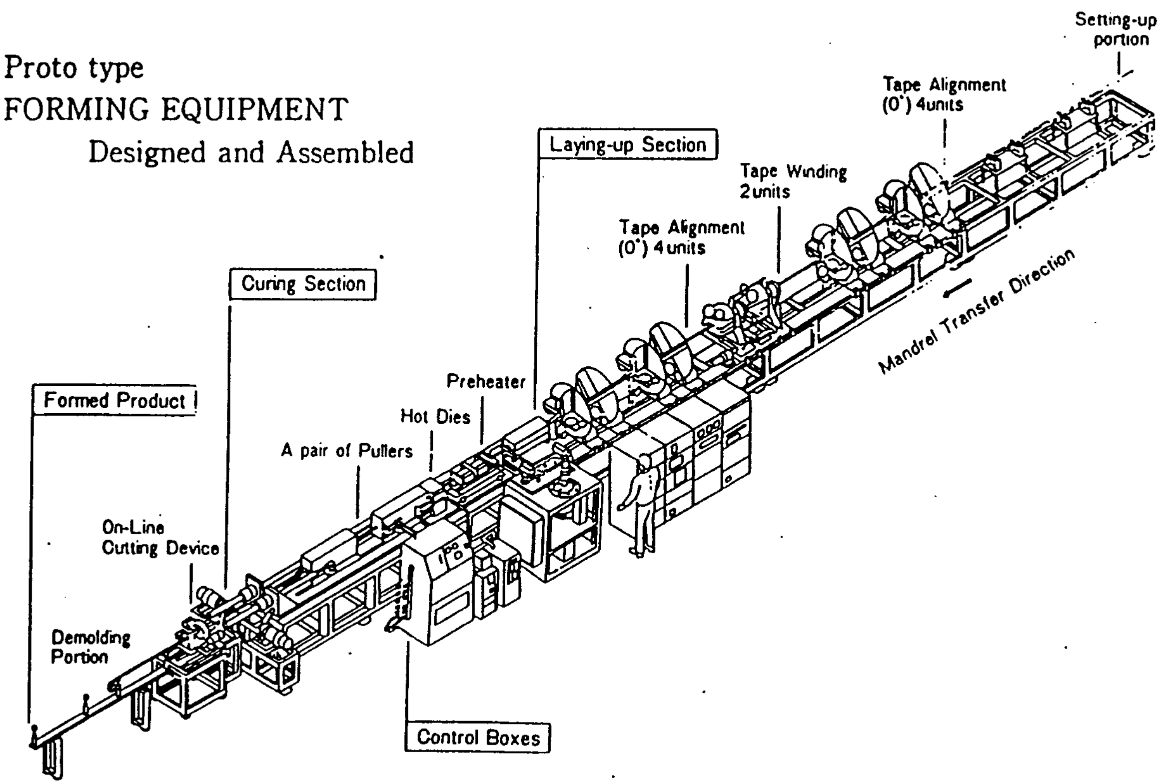


CONTINUOUSLY FORMED GRAPHITE/EPOXY COMPOSITE TUBES FOR LARGE SPACE STRUCTURE

FABRICATION
Combined Process of FW and Pultrusion
(Circular or Square Cross Sectional Tube)

PERFORMANCE
High stiffness, Thin Wall and High Precision
(Thickness 0.5 to 1mm, Vf 60% above)

Proto type
FORMING EQUIPMENT
Designed and Assembled



JAPANESE INTERNATIONAL COOPERATION

(PAGE 1)

- 1986 REVISION TO THE AIRCRAFT INDUSTRY PROMOTION LAW INSPIRED JAPANESE GOVERNMENT

  "TO PROVIDE SUPPORT FOR AIRCRAFT ONLY IN THE CASE OF INTERNATIONAL COOPERATIVE DEVELOPMENT PROJECTS" MITI

MITI PROVIDED TWO JUSTIFICATIONS FOR THE POLICY

1 HIGH RISK INVOLVED IN AIRCRAFT DEVELOPMENT (INTERNATIONAL COOPERATION IS NATURAL TREND)

2 JAPANESE POLICY TO ENCOURAGE INTERNATIONAL EXCHANGE OF TECHNOLOGY

JAPANESE INTERNATIONAL COOPERATION

(PAGE 2)

CURRENT INTERNATIONAL PROGRAMS

- BOEING B-777 (21%)
- IAE V-2500 COMMERCIAL ENGINE (23%)

FUTURE INTERNATIONAL PROGRAMS

- YXX 150-SEAT MEDIUM SIZE TRANSPORT (25%)
- YSX 50-100 SEAT SMALL TRANSPORT
- HIGH SPEED CIVIL TRANSPORT
- ULTRA LARGE AIRCRAFT (SUPER JUMBO)
- ENGINE DEVELOPMENT

JAPANESE INTERNATIONAL COOPERATION

(PAGE 3)

- JAPANESE AEROSPACE COMPANIES UNDERSTAND "LOW COST" KEY TO COMPOSITE MARKET EXPANSION
- JAPANESE COMPANIES FEEL THAT COOPERATION WITH U.S. NECESSARY FOR MARKET EXPANSION
- INTERNATIONAL STANDARDIZATION IS MUST
- TRANSFER OF TECHNOLOGY TO U.S. ALREADY STARTED
  - FSX TECHNOLOGY TO GENERAL DYNAMICS
  - YSX TECHNOLOGY TO BOEING
- THE MOST POWERFUL COMBINATION:
  - U.S. STRONG IN INNOVATION AND MARKETING
  - JAPAN STRONG IN INTEGRATION AND PRODUCTION

IMPORTANT FINDINGS FROM JAPAN VISIT

(PAGE 1)

- MANUFACTURING TECHNOLOGY SAME AS IN U.S.A.
- WITH THE SAME TECHNOLOGY JAPAN PRODUCES
  - HIGH QUALITY PARTS
  - ON TIME
  - WITH LESS COST IN MANY CASES
- ANSWER FOUND IN OTHER THAN TECHNOLOGY
  - JAPANESE CULTURE AND WAY OF THINKING
  - MOST IMPORTANT ASSET – PEOPLE
  - TRAINING, TESTING, RETRAINING, RETESTING
  - SET HIGHER STANDARD & GOALS; ZERO DEFECT
  - PAYING ATTENTION TO DETAILS
  - ASSIDUOUS EFFORT TO PERFECT FAB PROCESS

IMPORTANT FINDINGS FROM JAPAN VISIT

(PAGE 2)

- PUTTING MONEY AND EFFORT UP FRONT TO PREVENT DOWN STREAM PROBLEMS
- MANUFACTURING GETS HIGHEST PRIORITY
- SUPERIOR PRODUCTION AREA MANAGEMENT
- LONG RANGE OUTLOOK IN LIEU OF SHORT RANGE PROFIT

- MANUFACTURING TECHNOLOGY WORTH MENTIONING
  - LARGE SCALE COMPLEX CO-CURING
  - OMEGA STRINGER REINFORCED PANEL
  - CURVED PULTRUSION
  - 3-D AND 2.5D WEAVING
  - CONTINUOUSLY FORMED THIN-WALLED TUBES

Summary

- Japanese Aerospace Policy is International Cooperation
- U.S. - Japan Cooperative Programs Exist and More Are Coming
- The U.S. Can Learn How to Scope and Track Applied Research Projects by Having Cooperative Efforts
- If the Cost Effective Answer is Cocure, the Work Force Must be Educated to Accomplish the Task
- Japan Recognizes the Benefits of Slow Processes That Have Low Labor Content

Current and Year 2000 Projections for the Manufacture of Primary Aerospace Structure

	Sray Layup	Hand Layup	Auto Tape Layup	Ply Cut & Stack	Filament Wind	Tape Wind	Tow Placement	High Tech Pultrusion	RTM	Thermoform Epoxy	Composite Design for Manufacture	Thermoplastic
Current USA	○	●	◒	◒	●	◔	◔	○	○	○	○	◔
Current Japan	○	●	◒	◔	◒	◒	○	○	○	○	◒	◔
Japan 2000	○	●	●	◒	◒	◕	◔	◒	◒	○	◕	◒
USA 2000	○	●	◕	◔	◕	◔	●	◔	◔	◔	◒	○

● Ready for Production

○ Production Potential Dubious

DRG15-1/29/93

SPORTING GOODS

Joseph S. McDermott
Moto Ashizawa

INTRODUCTION

RELEVANCE AND BACKGROUND

APPLICATION OF COMPOSITES TO SPORTING GOODS

SPORTING GOODS MARKET

CURRENT FABRICATION TECHNOLOGY

FUTURE FABRICATION TECHNOLOGY

RELEVANCE AND BACKGROUND

SPORTING GOODS TOGETHER WITH AEROSPACE CURRENTLY DOMINATE COMPOSITES MARKET

PRODUCTION RATE 20/MONTH CONSIDERED AS HIGH IN AEROSPACE INDUSTRY

PRODUCTION RATE OF 100'S OR EVEN 1,000'S A MONTH COMMON IN SPORTING GOODS

LOW COST FABRICATION IN SPORTING GOODS MAY PROVIDE ANSWER TO AEROSPACE COST REDUCTION

AESTHETIC APPEARANCE IMPORTANT IN SPORTING

SPORTING GOODS APPLICATIONS

GOLF–CLUBS AND SHAFTS

FISHING POLES

BOWS AND ARROWS

CANOES, KAYAKS, WINDSURFING

MASTS FOR SAILBOATS

SAILBOAT HULLS

BASEBALL BATS

TENNIS RACKET

BICYCLES

BODY BLADE

OARS

SKIS AND POLES

TENT POLES

SKI EQUIPMENT

ETC.

SPORTING GOODS MARKET

- THREE PRIMARY PRODUCTS USING COMPOSITES
  - GOLF-CLUB SHAFTS
  - TENNIS RACKETS
  - BICYCLES
- 1.1 BILLION DOLLAR MARKET IN U.S.A.
- MARKET IS GROWING RAPIDLY
- 65% OF TOTAL COMPOSITE MARKET IN JAPAN
- 15% OF TOTAL COMPOSITE MARKET IN U.S.A.
- AMPLE ROOM FOR GROWTH IN U.S.A.
- COMPOSITE BIKES VERGE OF MARKET EXPLOSION

CARBON FIBER USAGE IN SPORTING GOODS

LARGE QUANTITY OF CARBON FIBERS USED IN SPORTING GOODS

CARBON FIBER USAGE IN 1989

UNIT: TONS

APPLICATION	USA	JAPAN	EUROPE	ASIA	TOTAL
AEROSPACE	1550	40	530	0	2120
SPORTING	400	720	270	1080	2470
INDUSTRIAL	550	350	300	10	1210

USAGE IN SPORTING GOODS EXCEEDS AEROSPACE

CURRENT FABRICATION TECHNOLOGY

(PAGE 1)

- MANY SPORTS PRODUCTS INVOLVE TUBULAR STRUCTURAL ELEMENTS
- ROLL WRAPPING BY HAND MOST COMMON
  - METHOD USED FOR OVER 20 YEARS
  - LIMITED MANUFACTURING SPEED
  - SEAM DOWN THE LENGTH
  - INCONSISTENCY IN PLY ORIENTATION
- FILAMENT WINDING
  - MACHINE CONTROLLED
  - LESS LABOR INTENSIVE
  - HIGH CAPITAL INVESTMENT
- TAPE WINDING AND FIBER PLACEMENT

CURRENT FABRICATION TECHNOLOGY

(PAGE 2)

- BRAIDING
  - MORE ECONOMICAL THAN FILAMENT WINDING
  - AUTOMATED FOR HIGH SPEED PRODUCTION
  - INTERLOCKING YARNS FOR BETTER IMPACT
- RTM (RESIN TRANSFER MOLDING)
  - NON-TUBULAR SHAPE
  - HIGH STRENGTH COMPLEX SHAPE
  - POTENTIAL FOR LOW COST
- COMPRESSION MOLDING
  - HIGH VOLUME PRODUCTION
  - NON-TUBULAR COMPLEX SHAPE
  - HOLDING HIGH TOLERANCE

AUTOMOTIVE

Joseph S. McDermott
Composites Services Corporation

JAPANESE AUTOMOTIVE COMPOSITES ACTIVITY
("BIG FIVE" ONLY)

	ACM activity	Non-metallic focus	U.S. affiliate
#1 Toyota	1. Racing car experimentation 2. Indirect license to access filament-wound CFRP drive shaft - no usage announced	Engineering thermo-plastics; Glass mat thermoplastics (GMT)	General Motors
#2 Nissan		Preoccupied with recycling issue	

Japanese Automotive Composites Activity

("Big Five" Only)

	ACM activity	Non-metallic focus	U.S. affiliate
#3 Mitsubishi			Chrysler, phasing into Daimler- Benz
#4 Honda			Most inter-nationalized
#5 Mazda	Prefers liquid crystal polymer route to high performance parts		Ford

Most Apparent Obstacles to ACS in Japanese Automotive Uses

1. Efficient, low-cost, high quality, thin sheet metal and tooling metals

2. Fleets have low CAFE mileage ratings.

3. No apparent offset at this time to cost penalties of new materials.

4. Recycling and other environmental issues are referenced.

North American Automotive Composites Profile

	Role/Emphasis	AC manufacturing
General Motors	Innovator since 1953, still dominant user of SMC, engineered composites	Pultruded CF/E driveshaft in established production. Also glass/epoxy leaf springs in light trucks.
Ford	Early driveshaft development, recent emphasis on RTM	Built LTD light-weight demonstrator of CFRP, early '80's.

North American Automotive Composites Profile

	Role/Emphasis	AC Manufacturing
Chrysler	Reliance on suppliers	"Top-of-tunnel" CF/E box on 1992 Viper, RTM by aerospace/industrial supplier.
Heavy truck ("Big 7")	Large exterior parts, for light weight, aerodynamics (FRP).	None Known, very cost-conscious
Automotive Composites Consortium	4-years old, generic pre-competitive research	Automation of RTM, SRIM preforms (glass).

Obstacles to AC Materials in North American Automotive Applications

1. Cost of raw materials and present manufacturing methods.

2. Sensitive to over-engineering

3. High interest in low cycle-time manufacturing, low cost tooling.

   (Added to parts consolidation and light weight = advanced manufacturing)

4. Recycling an issue, but manageable.

CIVIL ENGINEERING

Joseph S. McDermott
Composites Services Corporation

Vistasp M. Karbhari
Center for Composite Materials
University of Delaware

OUTLINE

- Motivation
- Material Forms and Applications
- Case Study
- Use in Bridge Structures and Rehabilitation
- Comments and Conclusions

111

USE OF COMPOSITES

- High stiffness/weight, strength/weight
- Easier to assemble
- Corrosion resistant
- Lower energy consumption during fabrication
- Reduced cost of transportation
- Easier installation
- Lower thermal conductivity

OVERALL REDUCED LIFE-CYCLE COSTS

BASE LINE STRENGTHS

Compressive Strengths	
Concrete	5,000 psi
Advanced Concrete	10-15,000 psi
Lab Conditions	45,000 psi

But

Tensile Strength $\leq$ 1,000 psi

MOTIVATION FOR REINFORCED CONCRETE

WHAT ABOUT REINFORCED PLASTICS: COMPOSITES?

NEED FOR COMPOSITES AS CONSTRUCTION MATERIALS

Steel corrodes, concrete does not....but....

	Density (g/cm^3)	Flexural Strength (psi)	Compressive Strength (psi)	Fracture Energy (J/m^2)
Portland Cement Paste	1.6-2	725-14,500	4,000-5,000	20
Advanced Polymer Concrete	2.3-2.5	14,500-21,750	22,000-36,000	300-1,000
Aluminum	2.7	21,750-38,000	42,000	10,000

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CHARACTERISTICS OF CONCRETES AND MORTARS IN WHICH IMPROVEMENTS / REPLACEMENTS COULD BRING BENEFITS

	Comp Strength	Flex or Tensile Str.	Uniform Appearance	Low Density	Modulus	Impact Resistance	Durability	Fracture Toughness	Freeze-Thaw Resistance	Sulfate, Salt Resistance	Early Strength
Panels		X	X	X		X		X			X
Beams	X	X			X		X	X			
Railroad Ties		X				X	X	X	X	X	X
Foundations	X	X								X	
Columns	X	X			X		X				
Slabs		X		X					X	X	

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CHARACTERISTICS OF CONCRETES AND MORTARS IN WHICH IMPROVEMENTS / REPLACEMENTS COULD BRING BENEFITS (cont'd)

	Comp Strength	Flex or Tensile Str.	Uniform Appearance	Low Density	Modulus	Impact Resistance	Durability	Fracture Toughness	Freeze-Thaw Resistance	Sulfate, Salt Resistance	Early Strength
Highways		X							X	X	
Canal Linings		X						X	X	X	
Tunnel Linings	X	X				X	X			X	X
Bridge Decks		X			X	X	X	X	X	X	
Nuclear Pressure Vessels	X	X									
Marine Construction	X	X							X	X	

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MOTIVATION FOR USE OF COMPOSITES IN CIVIL ENGINEERING

- Reduced to no deterioration due to corrosion, air-borne attack by industrial chemicals (chlorides, sulfates etc.), de-icing salts etc.
- Lighter construction material - significantly reduced dead load translatable to increased load capacity
- Easier to assemble, install, change - speed and cost
- Reduced costs of transportation to site
- Use of modular construction can be a reality
- Ease of use in terms of design flexibility

MOTIVATION FOR USE OF COMPOSITES IN CIVIL ENGINEERING (contd...)

- Cleaner/smaller worksites
- Lower energy consumption during fabrication
- Reduced maintenance/ life-cycle costs
- Use of sensing and monitoring equipment
- Lower thermal induced stresses and reduction of problems thereof

ADVANCED COMPOSITES

What are they?

- **Advanced Materials**
- **Advanced Processes**

- **What defines advanced?**
- **State of composites?**
- **State of the industry?**

DIFFERENCES IN PERSPECTIVES

AEROSPACE

- Very high performance
- Weight critical
- Extreme accuracy
- High M&P quality control
- CAD/CAM/CAE
- Small runs

High cost > $10/lb

AUTOMOTIVE

- Speed
- Flexibility
- Large production runs
- Medium accuracy

Cost Driven $1-6/lb

CIVIL ENGINEERING

- Environmental resistance
- Speed and retrofit
- High volume - low part count
- QC?
- Unskilled Labor

Cost and labor driven

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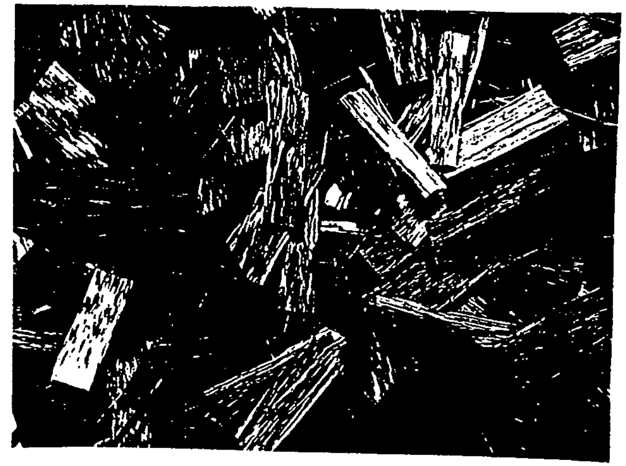
MAJOR APPLICATIONS IN CIVIL ENGINEERING

Short Fiber -	Curtain Walls, Free Access Floors, Slabs Cement Board
Continuous Fiber -	Reinforcing Elements, Slabs, External Walls
Cable Type Elements -	Prestressing/Post-tensioning Cables Cable Stays
3D Fiber Structures -	Columns, Beams, Slabs, Walls
Retrofit/Rehabilitation -	Columnar Structures, Chimneys, Pipes, Bridge Decks, Marine Structures

USE OF K661

- Coal pitch base
- Good mixing
- Higher Vf possible (>10%)
- Higher strengths
- Enhanced flexural performance
- Greatly enhanced toughness



DIALEAD™

Exterior uses - Curtain walls, Road barriers, Repair use in polymer concrete, aesthetic panels, corbels etc.

CHOPPED FIBER PROPERTIES

Type	Tensile Strength	Tensile Modulus	Elongation	Density	Fiber Length
	(ksi)	(Msi)	%	g/cm^3	in.
K223 (TPCs)	340	30	1.1	2.01	0.12, 0.24
K661 (Cement)	260	25	1.0	1.90	0.4, 0.75

USE OF CFRC / GRIDS FOR PANELS

CFRC - Carbon fiber reinforced cement (Mitsubishi Kasei)
NEFMAC - Grid type elements (Shimizu)

	Concrete	Composite/Concrete
Weight	Difficult to transport	Easy to transport 50% less weight
Damage	Quality control problems, corner damage, cracking, handling damage	Better quality control, tougher, easier to handle
Formability	Bar arrangement is difficult, formation of ribs is difficult	Casting and molding of complex shapes, use of decorative outcrops

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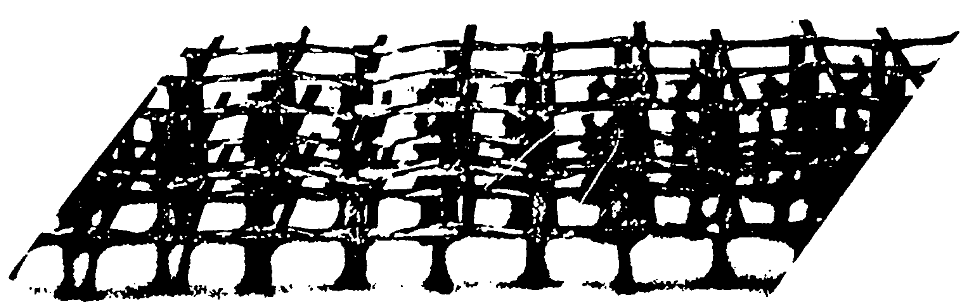
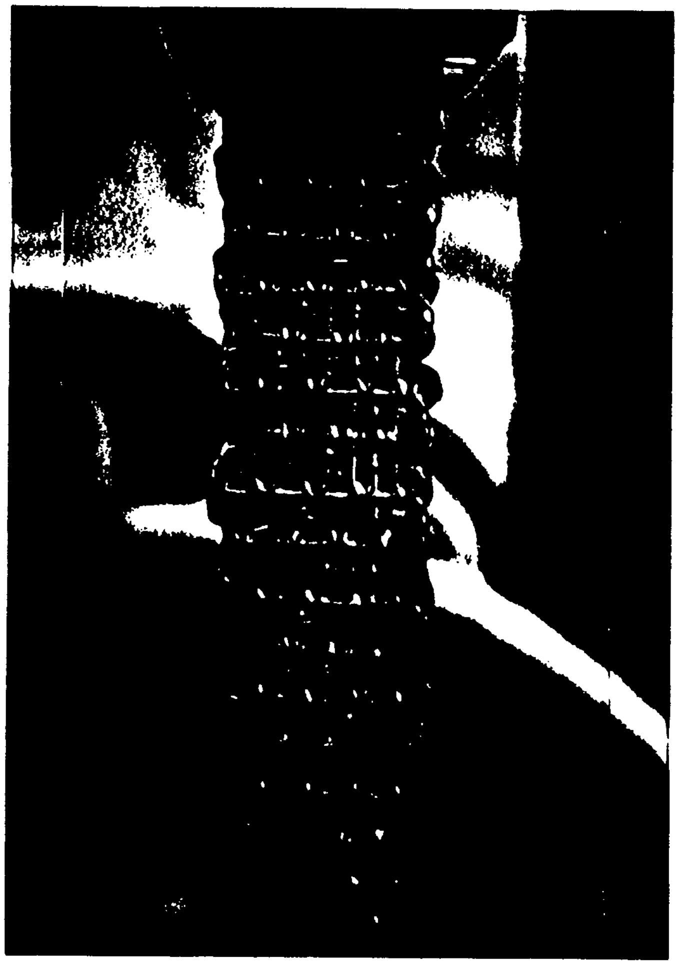
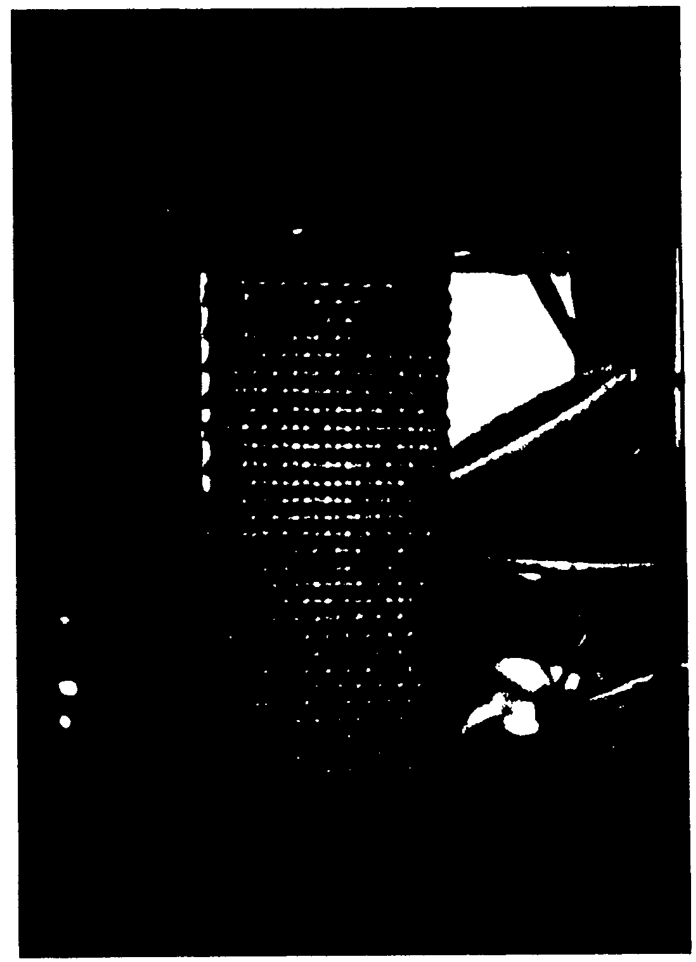
3D OPEN FABRIC ARCHITECTURES

- Novel 3D woven/braided open structures similar to rebar cage
- PAN based elements encased in epoxy
- Rigid structure with improved flexural properties
- Light weight
- Resistance to spalling



APPLICATIONS OF TEXTILE TECHNOLOGY





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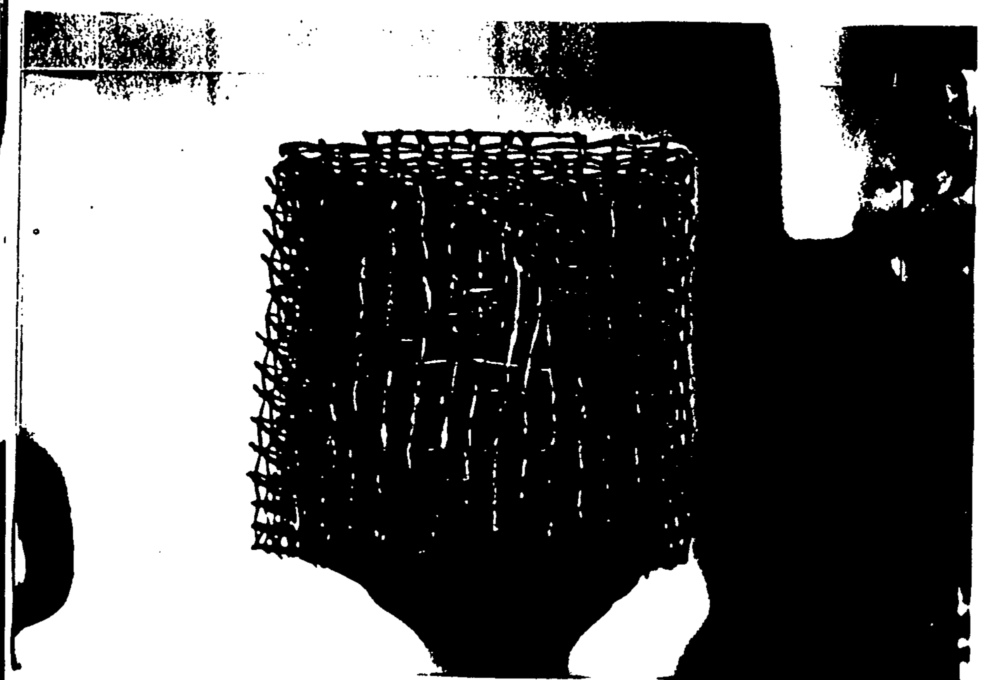
3D BRAIDED COLUMNAR STRUCTURE



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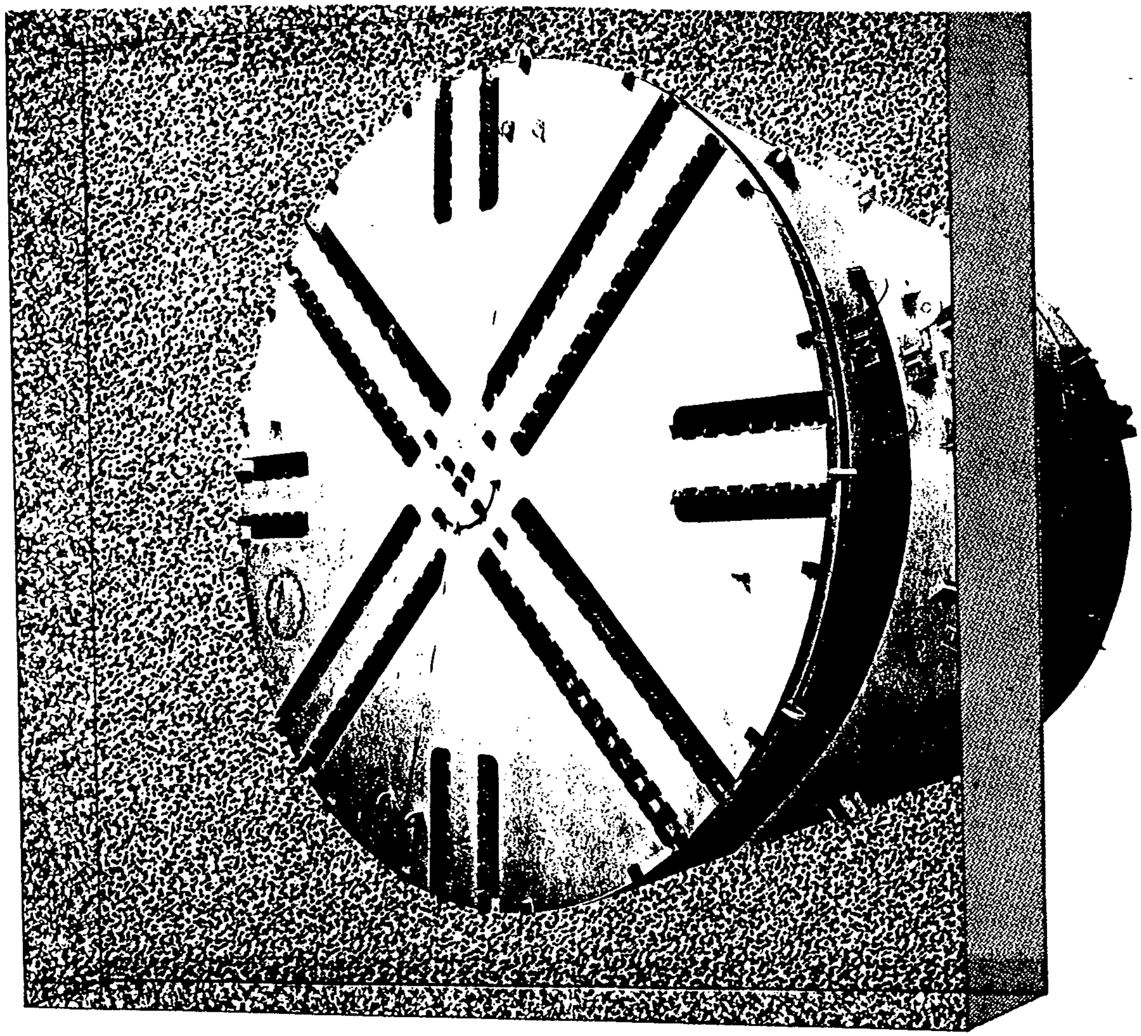
NOMST - NIPPON STEEL CORPORATION

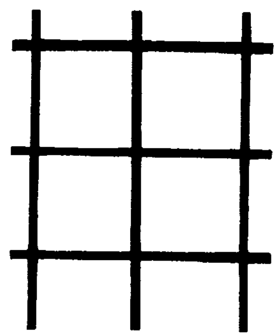


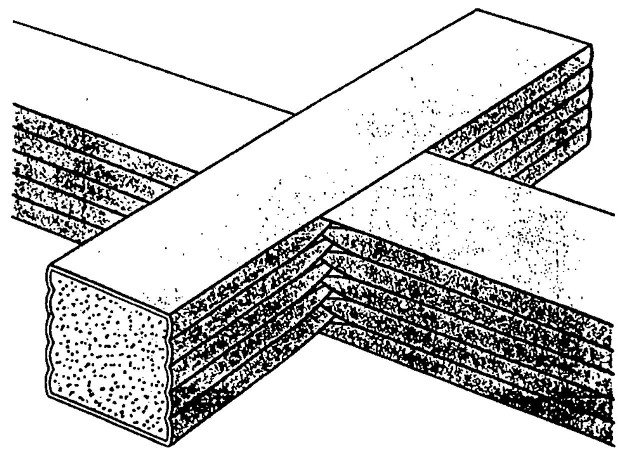
Novel Material Shield-cuttable Tunnel-wall system

- Chopped Fiber
- Cable type bar reinforcement

GRID STRUCTURES
(Shimizu)

- Use of glass, graphite, aramids and hybrids
- Use of Vinyl-ester, Poly-ester, epoxies





- Cross structure provides bond, anchorage and load transfer
- Alternate lamination at grid points gives additional constraining effect

SALIENT FEATURES OF GRID SYSTEMS

- Light, easy to place (Sp. gravity ≤ 2)
- Does not corrode
- Lower amount of cover needed and placement is easier
- Hinders spalling of concrete
- Deflection and performance are similar to steel reinforced concrete systems till 600˚C (degradation of the resin leads to joint failure - braided/woven structures could overcome this)

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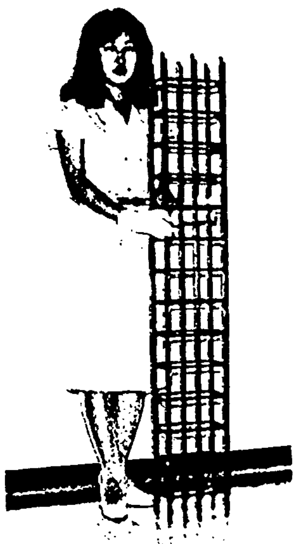
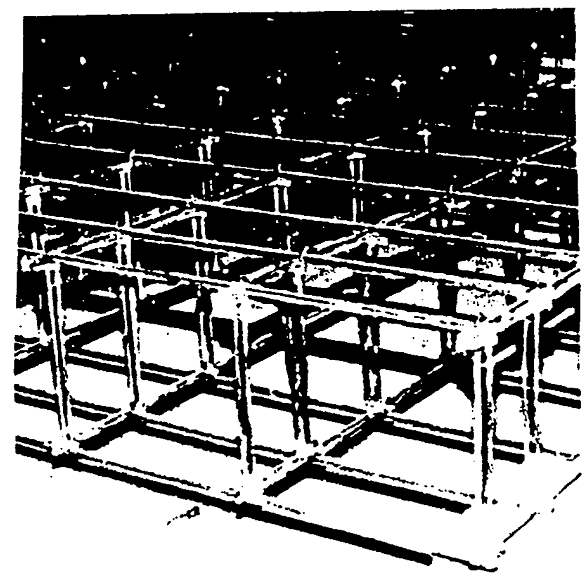
APPLICABILITY OF GRID STRUCTURES

- Column reinforcement
- Segmental rings for tunnels
- Modular deck structures





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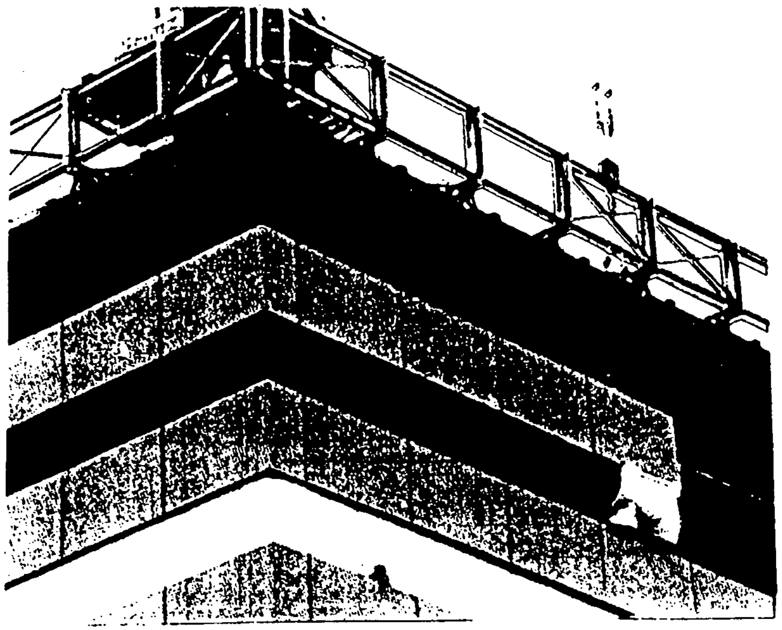
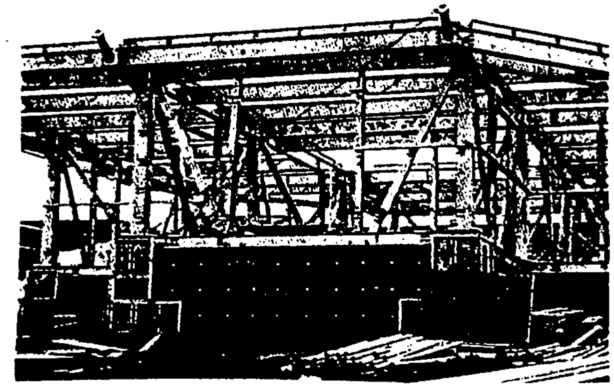
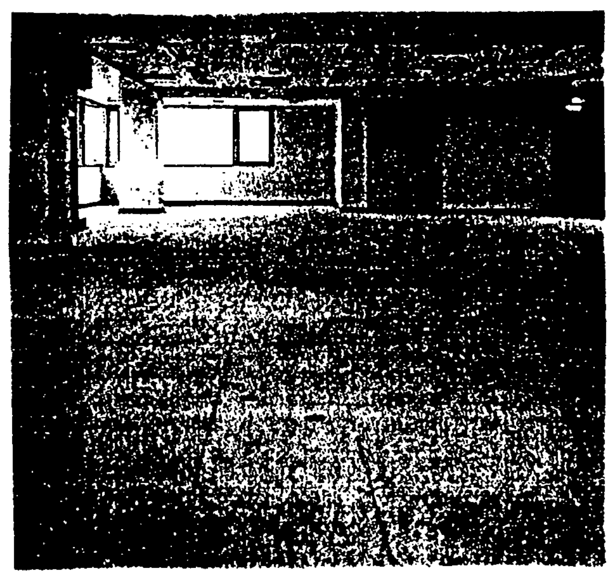
APPLICABILITY OF GRID STRUCTURES

- Slabs, curtain-walls, non-magnetic structures
- Base/foundation reinforcement in cold-regions type environments







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OVERALL PERSPECTIVE

Shimizu Corporation

Construction Technology

- New Materials
- New construction techniques
- Data processing systems

Ergonomics

Land Development
Leases

Facilities
Management

Social Development

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SHIMIZU - RESEARCH ACTIVITIES

- Shimizu Institute of Technology (1944)
- Development of design codes for use with composites
  - International Consortium
- Active program with suppliers
  - Asahi glass, Toray, Nippon Steel
- Member of MITI consortium
- Active role in University based research in materials and manufacturing
- Application/development of appropriate manufacturing techniques

(Results - 1991-92 sales of NEFMAC were $2 million)

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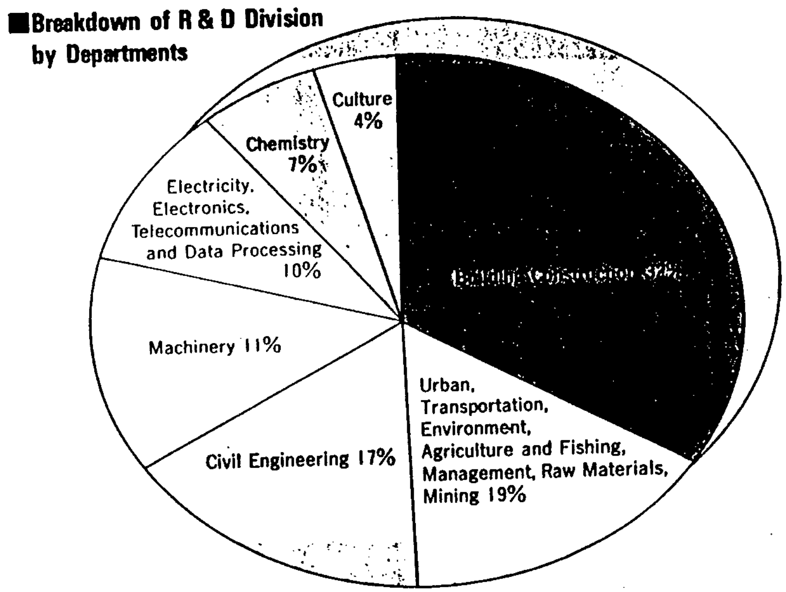
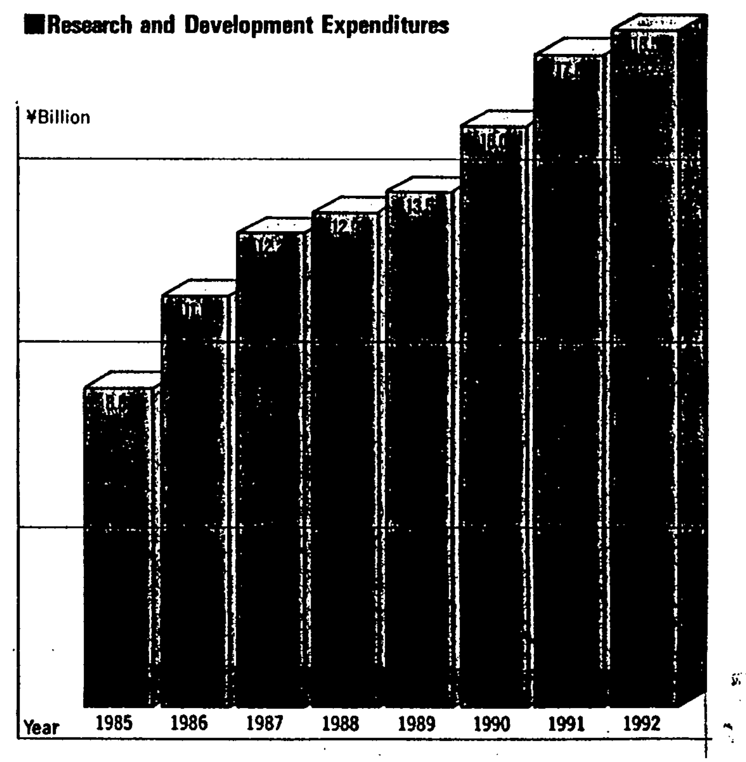
R&D EXPENDITURE
(Shimizu)





Often 1-5% of the total budget

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RESEARCH AND DEVELOPMENT OF GRID-TYPE FRP REINFORCEMENT: AN OUTLINE OF COOPERATIVE RESEARCH LED BY SHIMIZU CORP.

AIM	PRACTICE
Clarification of Fundamental Properties of FRP Reinforcement	
Clarification of Tensile Strength of Fibers	Relationship of Tensile Strength Between Fibers and FRP
Clarification of Mechanical Properties	Tensile Strength, Hybrid Effect
	Compressive Strength
	Shear Strength
Clarification of Behavior under Reversed Cyclic Load	Reversed Cyclic Loading (Tension and Compression)
Clarification of Anchorage Mechanism	Anchorage to Concrete (by Bending or Grid-shaping)

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RESEARCH AND DEVELOPMENT OF GRID-TYPE FRP REINFORCEMENT: AN OUTLINE OF COOPERATIVE RESEARCH LED BY SHIMIZU CORP. (cont'd)

AIM	PRACTICE
Clarification of Durability	Lapped Joint
	Deterioration of Tensile Strength Under Spa Atmosphere
	Creep Strength
	Chemical Resistance under Constant Tensile Deformation
Clarification of Heat Resistance	Tensile Strength under/after Heating/Cooling
Proof of the Applicability to Concrete Structures	
Application to Earthquake-resisting Wall	Behavior under Reversed Cyclic Lateral Loading

RESEARCH AND DEVELOPMENT OF GRID-TYPE FRP REINFORCEMENT: AN OUTLINE OF COOPERATIVE RESEARCH LED BY SHIMIZU CORP. (cont'd)

AIM	PRACTICE
Application to Precast Wall Structure	Shear Resistance of Vertical Joint
Application to Wall Panel	Bending Ultimate Strength
	Fire Resistance
Application to Slab Panel	Anchorage to Beam
	Long-term Deflection
	Bending Ultimate Strength
	Fire Resistance
	Effectiveness of Prestressing

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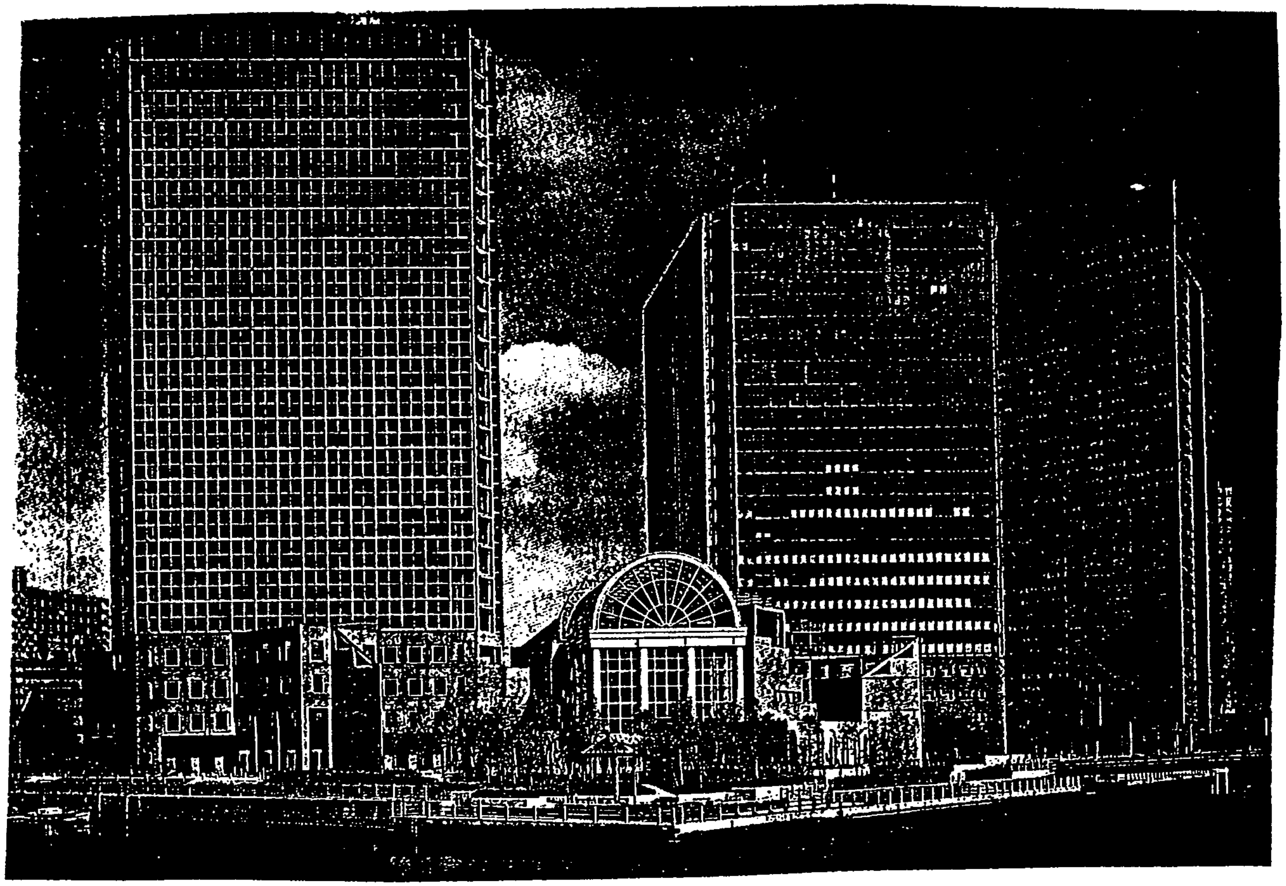
RESEARCH AND DEVELOPMENT OF GRID-TYPE FRP REINFORCEMENT: AN OUTLINE OF COOPERATIVE RESEARCH LED BY SHIMIZU CORP. (cont'd)

AIM	PRACTICE
Application to Beam and Column	Effectiveness of Chemical Prestressing
	Confined Effect by Lateral Reinforcement
	Fatigue Strength
	Bending Ultimate Strength after Sustained Loading
	Bending Ultimate Strength, Reinforced with Exposed FRP in Air
	Effectiveness of Chemical Prestressing

DEMONSTRATION OF GRID VIABILITY



Floor slabs were in part reinforced with NEFMAC:

- **Faster**
- **Lighter**
- **Cheaper (materials vs. labor, equipment etc.)**

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STANDARD PROPERTIES OF NEFMAC

Fiber Type	Specific Gravity	Tensile Strength (kg/mm^2)	Tensile Modulus (kg/mm^2)
Glass	1.70	60	3,000
Glass/Carbon	1.65	53	3,700
Carbon	1.42	120	10,000
Aramid	1.28	130	5,700

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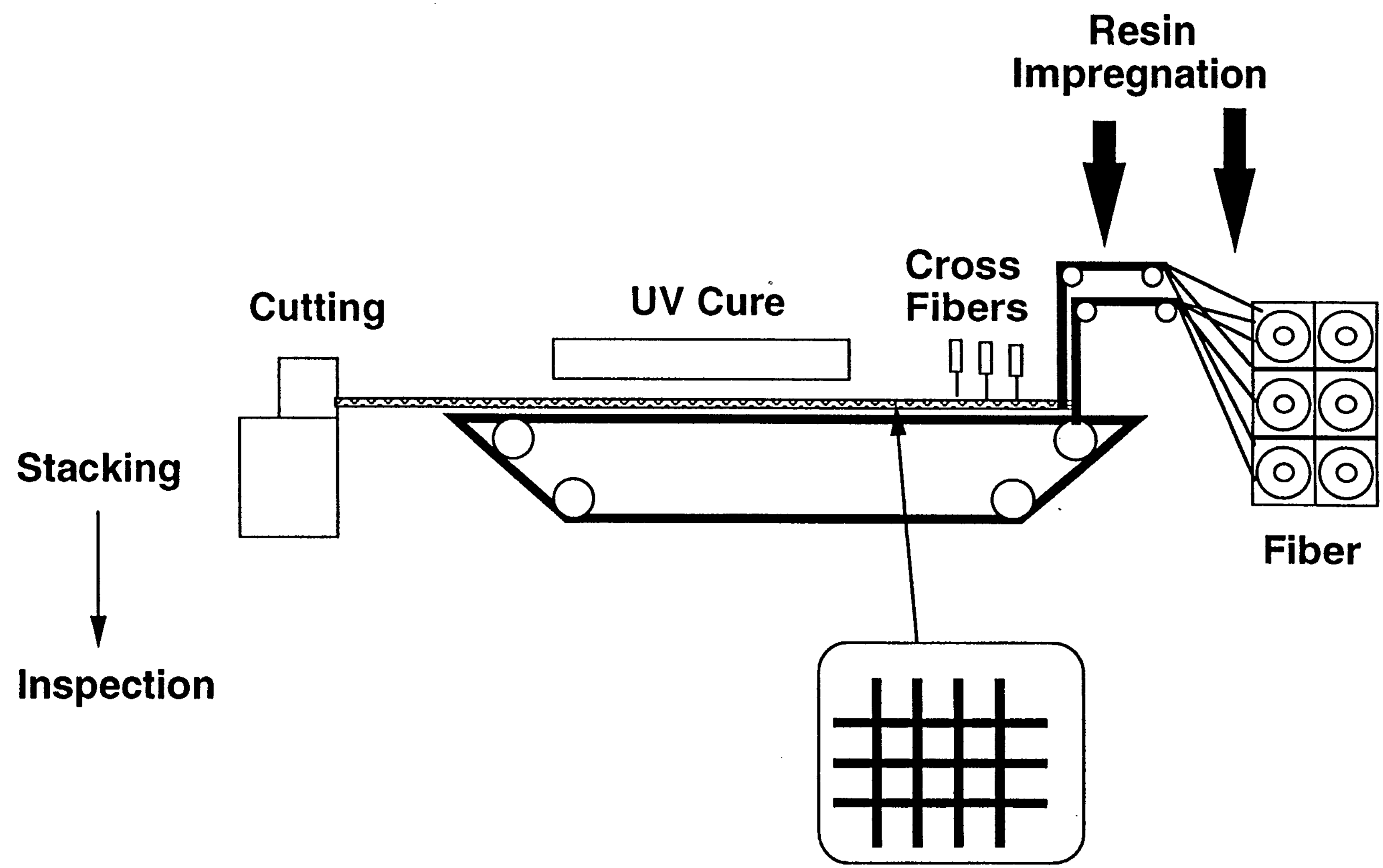
NEFMAC PROCESS

(Shimizu)



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BRIDGES AND DECKS

- Reduced weight - longer spans, greater capacity
- Simpler construction - reduction in large equipment
- Aseimic design with better characteristics
- Non-corrosive
- Modularity
- Multifunctionality through design
- Easy and quick repair
- Quick installation

CABLE-STAYED BRIDGES

Use of composites:

- Better in fatigue
- Inert to corrosion
- Lower weight
- Less replacement and maintenance
- Longer spans possible
- Better dynamic response
- Lower coefficient of thermal expansion

PRESTRESSING / POST-TENSIONING TENDONS

- Non-magnetic
- Impermeable to effects of sodium chloride
- No corrosion
- Lighter and easier to handle

- Long term durability?
- Anchoring and fixtures?
- Effects of breakage?

EFFICIENCY OF COMPOSITE CABLES

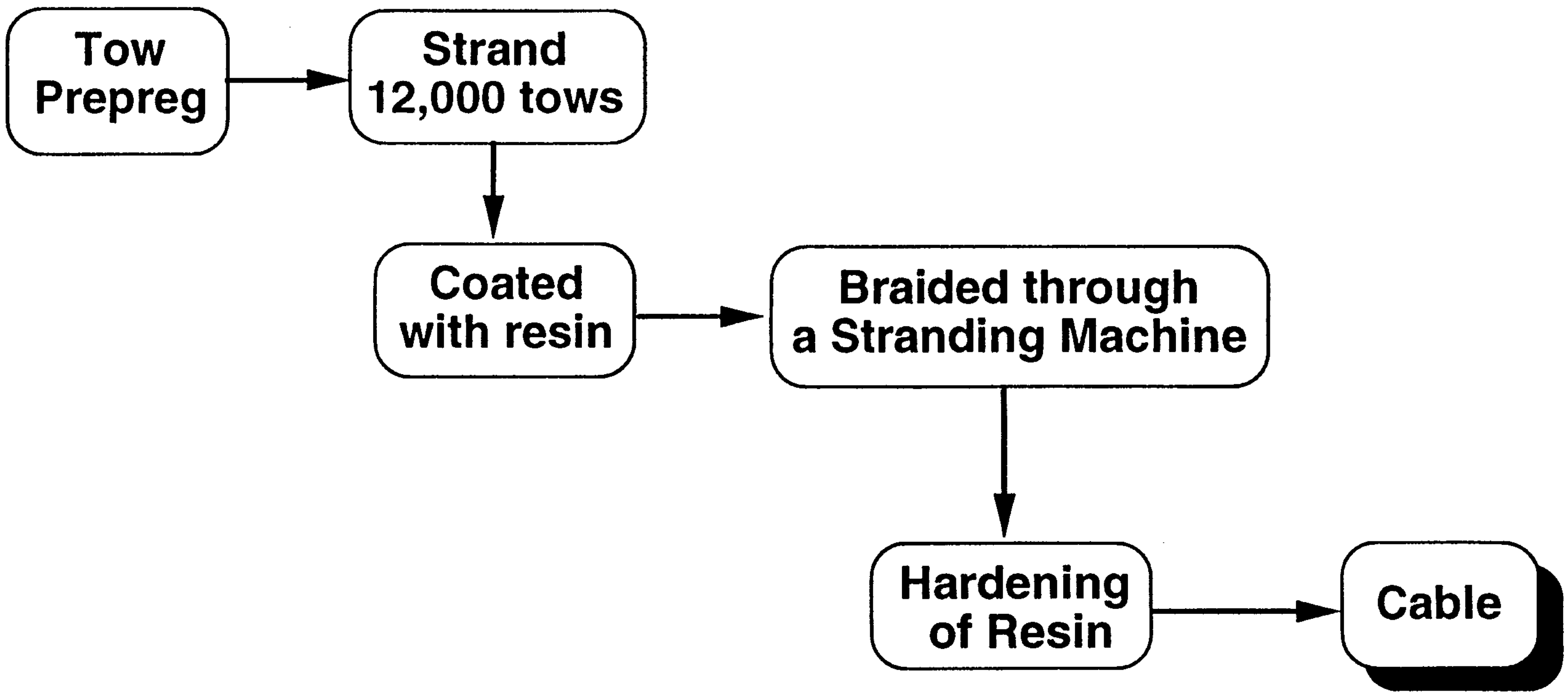
(data from Tokyo Rope Manufacturing Co. Ltd.)

Material	Diameter	Strands	Breaking Load	Unit Weight	Maximum distance between support points
	(mm)	(No.)	(kgf)	(kg/m)	(m)
Carbon	25.0	19	45,500	0.58	19,400
Galvanized Steel	25.0	19	52,700	3.09	4,220

FABRICATION METHOD FOR CABLES

Tokyo Rope

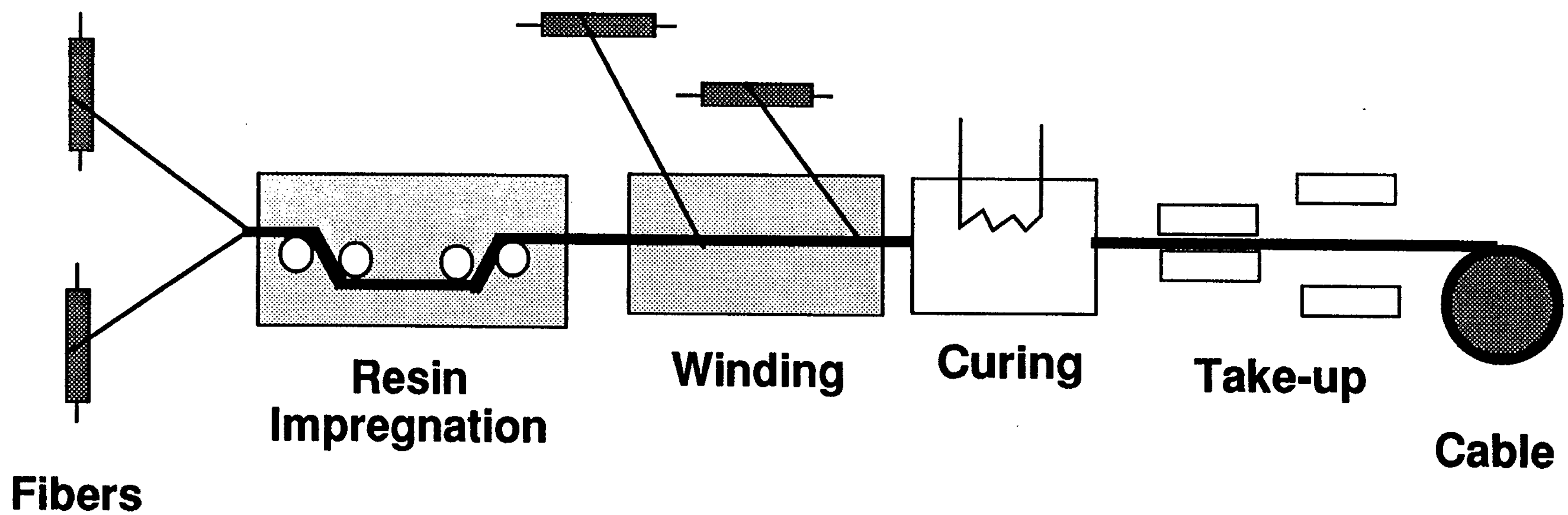
Carbon Prepreg is stranded and treated with a special coating



FABRICATION METHOD FOR CABLES

Teijin

Pultrusion of para-aramid fiber material
Copoly(p-phenylene 3,4'- oxydiphenylene-terephthalamide)



COLUMN CONSTRUCTION

Square section CFRP tubes with internal stiffening ribs filled with concrete

- reduced labor costs
- costs are much less than reinforced concrete and comparative to those with steel
- smaller c/s (50% of RCC, 80% of steel)

- Development of low cost braiding/weaving techniques
- Development of combined pultrusion/wet layup technique
- Use of wet-winding

Approval for general use granted by the Ministry of Construction

NEED FOR REHABILITATION / REPAIR

- Alkali neutralization
- Powdering and spalling
- Corrosion of reinforcing steel
- Swelling
- Separation of steel and concrete
- Cracking
- Seismic resistance
- Increased performance requirements

There is a need for simple, yet effective methods i.e. development of appropriate manufacturing techniques and materials

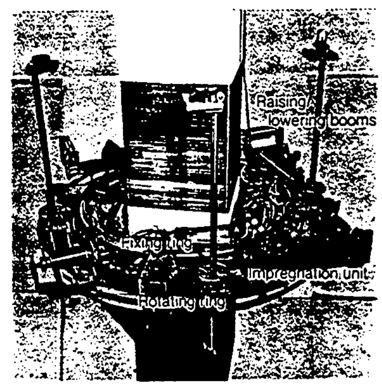
SEISMIC RETROFIT

- Response to the 1968 Tokachi-oki earthquake
- Lighter repair elements
- Longer service life
- Ease of placement (TONEN)

  or

- Robotization (Mitsubishi Kasei/Ohbayashi Corporation)

RETROFIT SCHEMES



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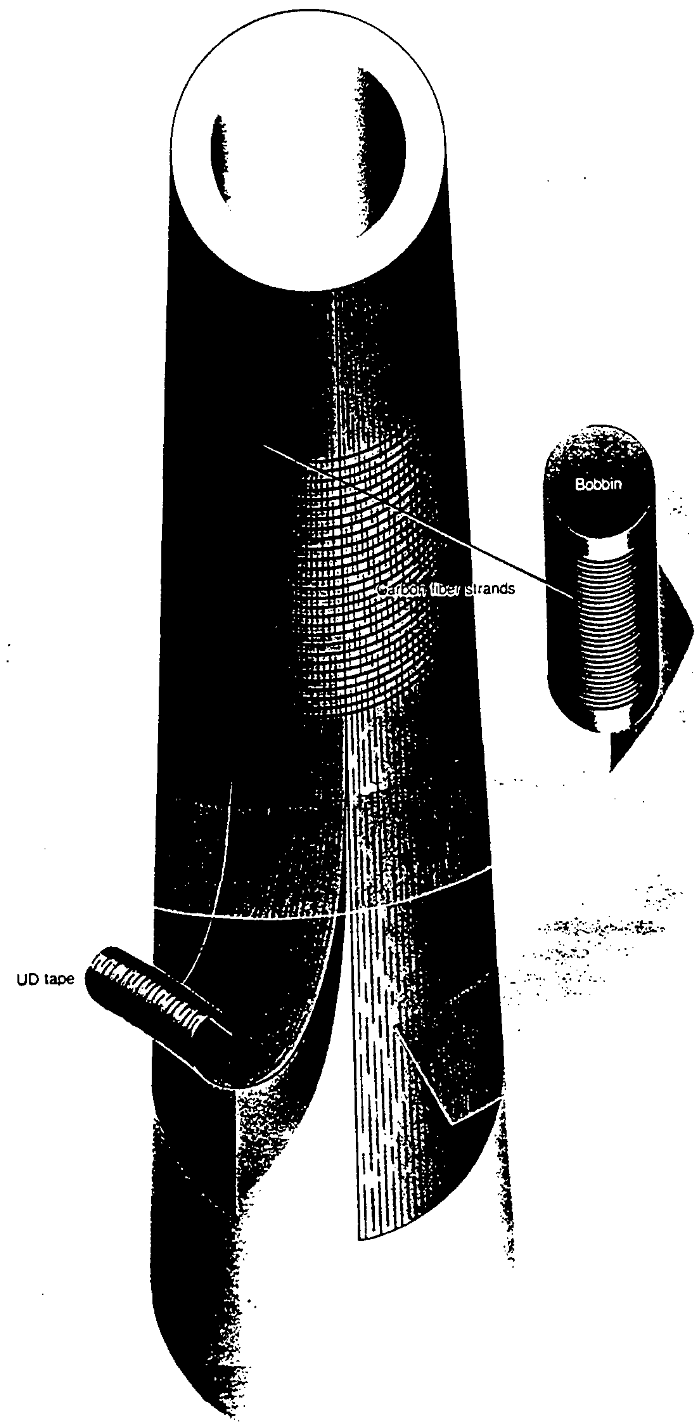
MITSUBISHI
KASEI

OHBAYASHI CORPORATION

RETROFIT SCHEMES



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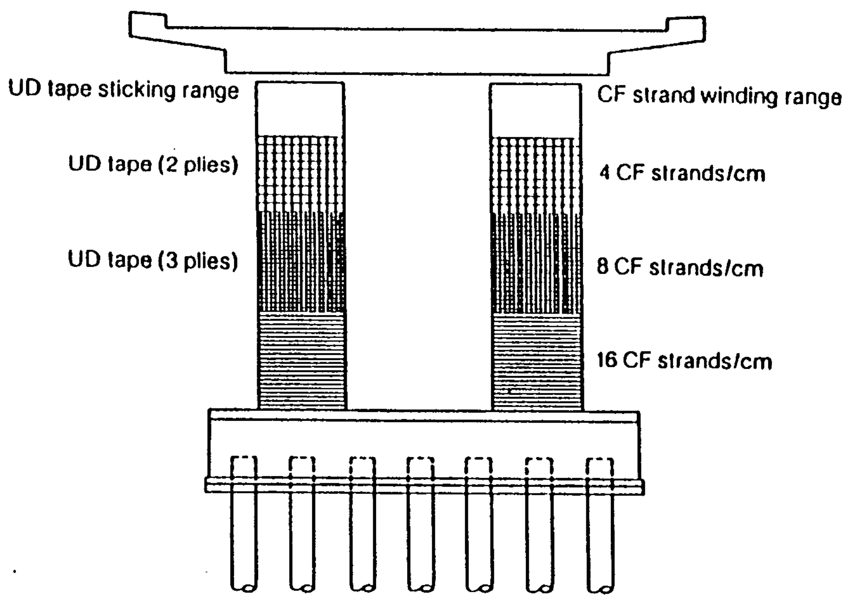
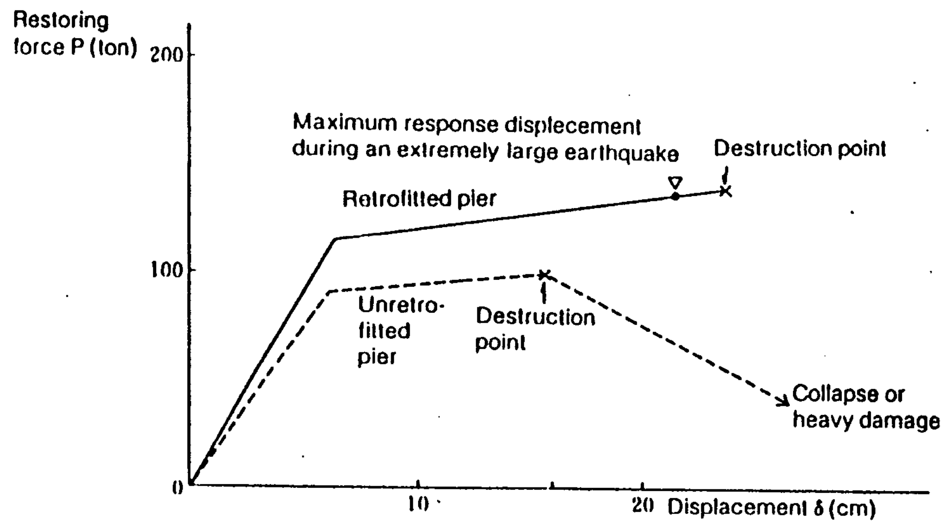
MITSUBISHI KASEI

OHBAYASHI CORPORATION

CONCEPTUAL RETROFIT OF A PIER





A study of restoring force characteristics and the response displacement before and after the retrofitting of the bridge pier.

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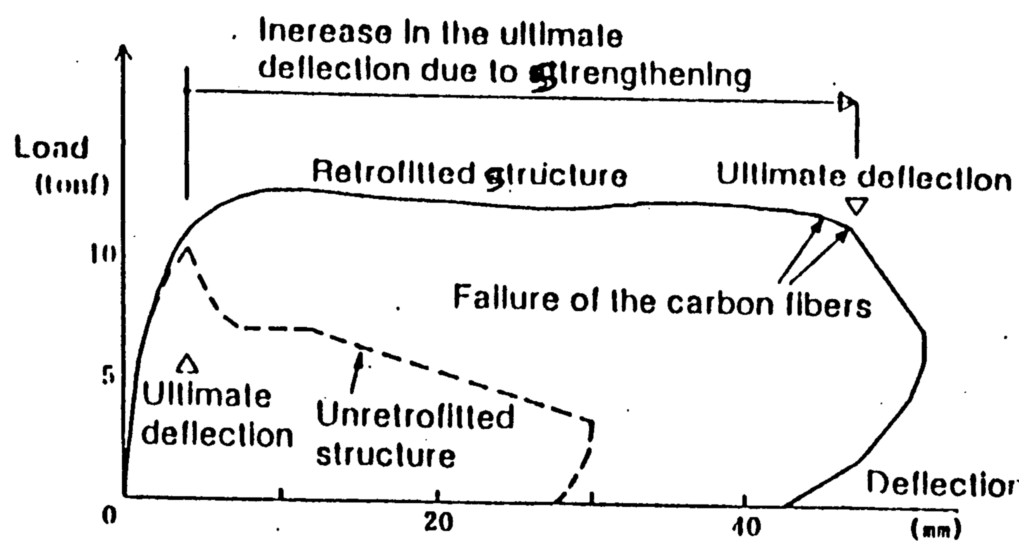
IMPROVEMENT OF TOUGHNESS

- Constraint
  - hoop reinforcement
  - greater toughness and enhanced ultimate deflection
- Prevents further spalling and environmental degradation
- Strengthening through increased load carrying capacity



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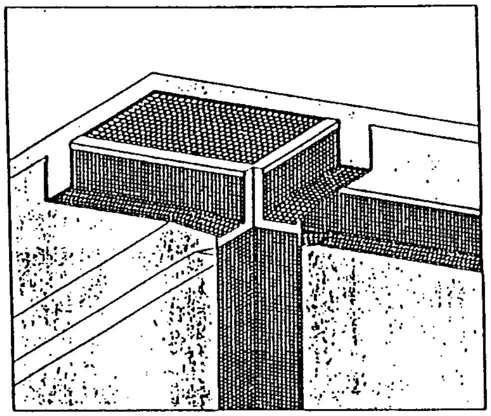
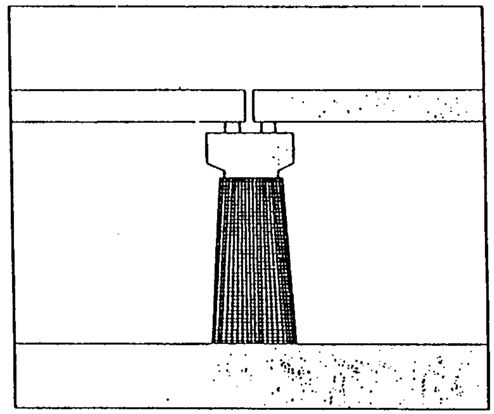
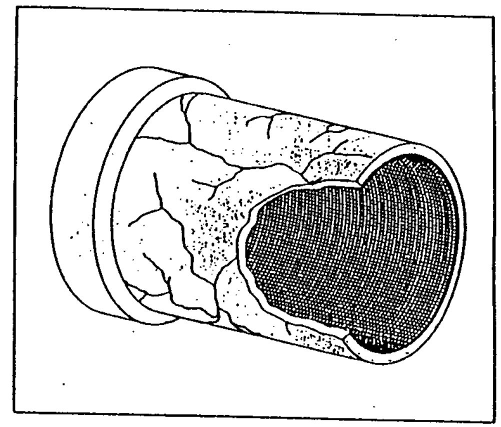
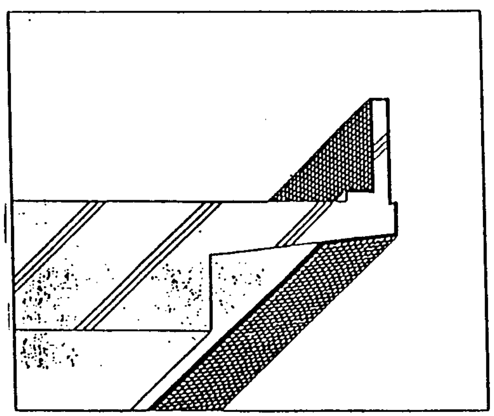
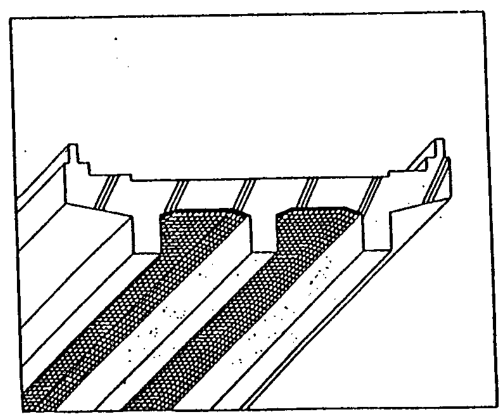
APPLICATION TO REHABILITATION

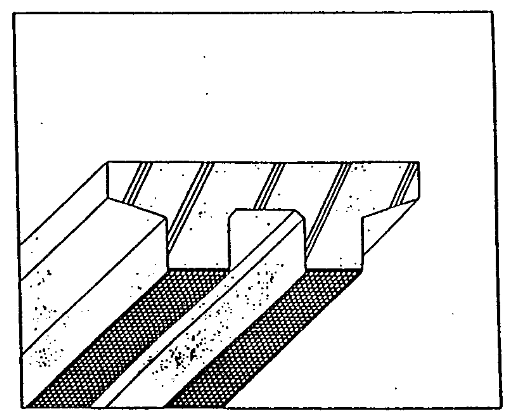












Construction - key features

1. Twenty-five engineering/construction firms have R&D laboratories, compared to five in the U.S.

2. "Pull-through" by end-users is widespread.

3. Emphasis on design data, standards, codification. (liability assumed up front)

Construction-key features (page 2)

4. Willingness to test full-scale, and develop instrumentation for quality assurance, is demonstrated.

5. "Mundane" activity elevated to high technology as part of global development.

6. But a large part of publicized developments are prototypes and demonstrations.

GROUP ACTIVITIES AIMED AT PROMOTION

Building Research Institute -	National project on application to bridges (1898 -)
Public Works Research Institute -	National project on development of alternatives to rebar (1988-1992 +)
RIPT/MITI	Development of 3D woven forms
Private Consortia	• Development of composite cables • Development of continuous fiber applications • Development of design codes and data

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GROUP ACTIVITIES AIMED AT PROMOTION (...cont.)

Japan Society of Civil Engineering	Research Committee on use of fiber reinforced concrete
Japan Society of Construction	Research Sub-committee (applns.)
Japan Society of Steel Construction	Applications group for new materials for structural elements
Japan Ocean Industries Assoc.	Research Committee for new material in marine structures
Japan Technology Transfer Assoc.	Research Committee on durability of new material for marine structures

KEY THEMES FOR CONSTRUCTION COMPANIES IN JAPAN

- Information related services (transportation)
- Globalization (integration)
- Improvement of cities (infrastructure)
- Enjoyment of leisure time (aesthetics)
- Need for overall higher quality of life (new materials and technologies)

MATERIALS

Jon B. DeVault
DARPA

Advanced Fabrication Technology for Polymer Composite Structures

Materials

J. DeVault

February 18, 1993

WORLDWIDE DEMAND FOR PAN BASED CARBON FIBER

(Unit:ton/year)

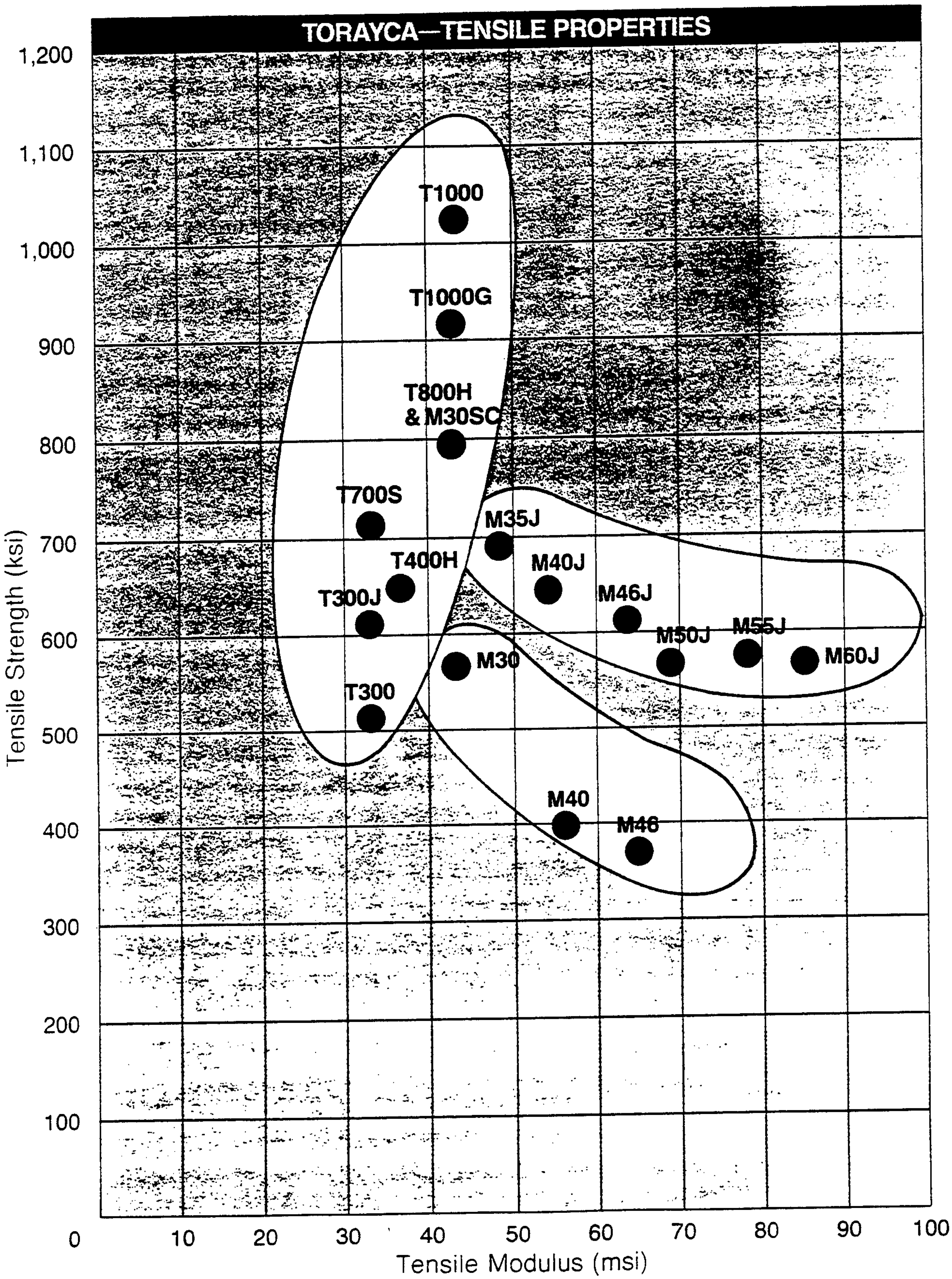
	1989	1990	1991	1992	1993	1994	1995
North America	2500 (2363)	2400 (2227)	2200 (2136)	2300 (2273)	2800 (2773)	3400 (3364)	4000 (3909)
Europe	1100 (909)	1250 (1045)	1260 (1181)	1400 (1409)	1550 (1590)	1750 (1864)	2000 (2045)
Far East & Others	1090 (1090)	1200 (1181)	1350 (1318)	1400 (1409)	1450 (1455)	1550 (1590)	1650 (1727)
Japan	1110 (1090)	1250 (1181)	1360 (1275)	1400 (1364)	1500 (1455)	1600 (1590)	1700 (1682)
Total	5800 (5454)	6100 (5636)	6170 (5909)	6500 (6454)	7300 (7272)	8300 (8409)	9350 (9363)

Forecasted in February 1992 by TORAY IND, Inc.
(Forecasted in February 1992 by SACMA)

WORLD PRODUCTION CAPACITY OF PAN BASED CARBON FIBER (TON/YEAR)

Asia	TORAY	2,250
	Toho	2,020
	Asahi Kasei	450
	Mitsubishi Rayon	500
	Taiwan Plastic	230
		5,450
USA	Hercules	1,715
	BASF	1,350
	Amoco	850
	Akzo	360
	Grafil	320
	Zoltek	60
		4,655
Europe	Akzo	500
	Soficar	700
	Sigri	100
	R.K. Carbon	100
		1,400
	TOTAL	11,505 ton/year

Data from TORAY, August 1992


TORAYCA—TENSILE PROPERTIES
Tensile Strength (ksi)
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
Tensile Modulus (msi)
T1000
T1000G
T800H
& M30SC
T700S
T400H
T300J
T300
M35J
M40J
M46J
M50J
M55J
M60J
M30
M40
M46

166

WORLD PRODUCTION CAPACITY OF PITCH BASED CARBON FIBER (TON/YEAR)

<u>Asia</u>	Kureha Chemical	900
	DONAC	300
	Mitsubishi Kasei	500
	Nippon Oil	50
	Nippon Steel	50
	Tonen	12
	Petoca	12
<u>USA</u>	Amoco	230
	TOTAL	2,054 ton/year

Data from TORAY, August 1992

MITSUBISHI KAISEI DIALEAD ®

COAL TAR PITCH-BASED CARBON FIBER

	TYPE	TENSILE STRENGTH KSI	TENSILE MODULUS MSI
CONTINUOUS FIBER			
	K321	290	25
	K133	340	65
	K135	370	80
	K137	390	95
	K139	400	110
CHOPPED			
	223	340	30
	661	260	25

MITSUI TOATSU CHEMICALS, INC.
PIX (THERMOPLASTIC POLYMIDE) CF PREPREG

MECHANICAL PROPERTIES

Matrix Resin	Compression Strength (kgf/mm^2)	Tensile Strength (kgf/mm^2)	CAI Strength (kgf/mm^2)	Continuous Use Temp. (°F)
PIX/T-800	*143*	*251*	*36.2*	*450*
PEEK/AS-4	111	213	31	300
Epoxy/T-300	140	143	14	<300

1. Outstanding Heat Resistance
2. Excellent Toughness
3. Good Processability

3-D COMPOSITES RESEARCH CORPORATION

Established: March 1988

Members:

- Mitsubishi Electric
- Nippon Steel
- Toyota Automatic Looms Works, Ltd.
- Mitsubishi Rayon
- Arisawa Manufacturing Co.

Charter: Develop 3-D Preforms and Molding Technology

Timing/Funding:

- 6 Year Program
- $16 Million

SUMMARY OF FINDINGS ON MATERIALS

- Agree on Market Size for Pan-Based Carbon Fibers
- Japan Still Aggressively Pursuing Pitch Fiber
- Japan Appears to be Doing Significant Work on RTM
- Matrix R&D Focus is High-Temperature Resins
- Japan is Clear World Leader in Pursuing Civil Engineering Applications for Carbon Fiber

MANUFACTURING SCIENCE

Vistasp M. Karbhari
Center for Composite Materials
University of Delaware

JTEC Summary: Manufacturing Science and Basic Research
Vistasp M. Karbhari
February 16, 1993

In an effort to expand the applications for polymer composite structures, the United States government convened a panel to evaluate the status and outlook for manufacturing technology in the U. S. and Japan, with an eye toward finding or developing mechanisms of cooperation. A 10-person team visited approximately 20 Japanese organizations over a 10-day period in December 1992. They drew a number of general conclusions, the most important of which is that individual organizations in both Japan and the United States practice the same basic manufacturing technologies, but Japanese companies practice them with a much greater respect for detail. The U. S. focus tends to be academic and fundamental, while that in Japan is applications driven. This summary provides an overview of the manufacturing science area; a full report, to be completed later in 1993, will include detailed conclusions.

For the purpose of this assessment, manufacturing science is defined as "the understanding of the process by which material, labor, energy, and equipment are brought together to produce a product having a greater value than the sum of the individual inputs." The manufacturing science of composites recognizes the coupling of the three decision areas of materials, configuration, and processes, in that a choice of a specific aspect of any of these classes necessitates simultaneous choices in the others due to their interdependence. The simultaneity of decisions necessitates the development of an integrated science base for the manufacturing of composites to enable optimization and development of a system before actual manufacture. In the U. S. version of the intelligent manufacturing system, process understanding drives the idea of integrated manufacturing established through the appropriate use of *process models*, *sensors*, and *control systems*.

In an idealized Japanese manufacturing science system, design, materials, fabrication, and inspection are integrated, but they are built on a foundation of *rules*, *people*, and *detail* in contrast to the aforementioned foundation of models, sensors, and controls in the U. S. In contrast to modeling efforts in the U. S., Japanese manufacturing science expertise appears to reside in experienced workers who understand the processes over long periods of time. Detailed process knowledge is collected and used for the internal education of employees, and materials and process information is handed down as a series of comprehensive rules and guidelines. As a specific example, in the area of quality control the Japanese approach includes testing, statistical analysis, and the development of NDI techniques, as might be expected, but attention to detail and human factors are also considered.

Based on the observations made during the panel members' visit to the Japanese facilities, the following keys to their success in manufacturing were identified:

- People factors, extensive testing, and attention to detail.
- Assiduous effort to perfect fabrication processes.
- Upfront effort and concurrent engineering to prevent downstream problems.
- Detailed and superior production area management.
- Long-range planning and individual honor.

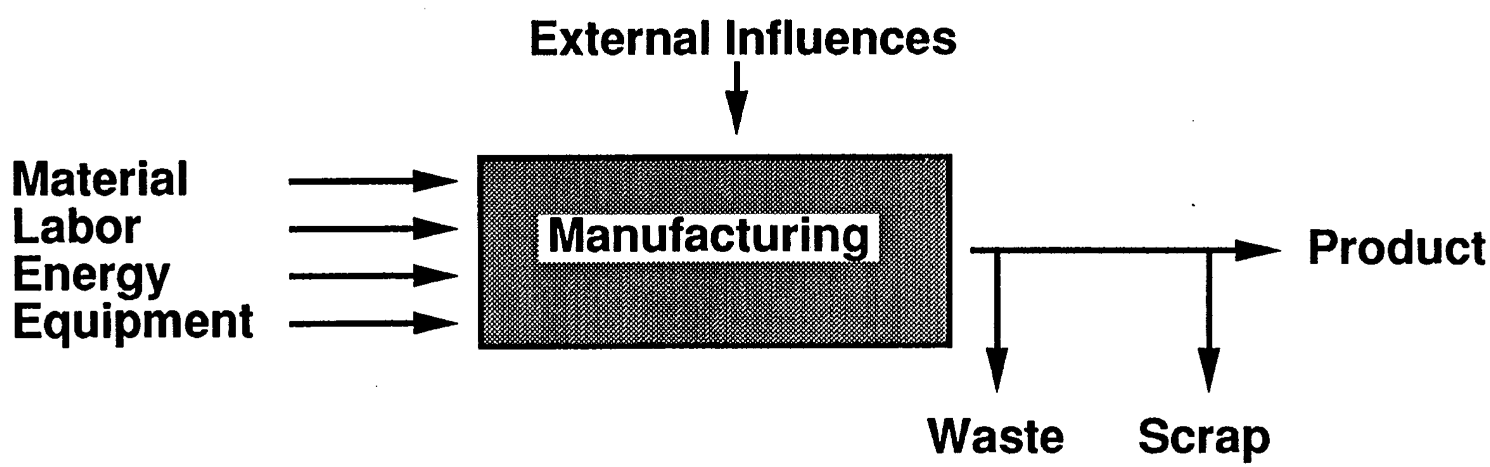
The overall conclusion: If a focus on improving the things that work and changing those that don't can be brought to American manufacturing, the United States can be the best. *But change must start at the top.*

OUTLINE

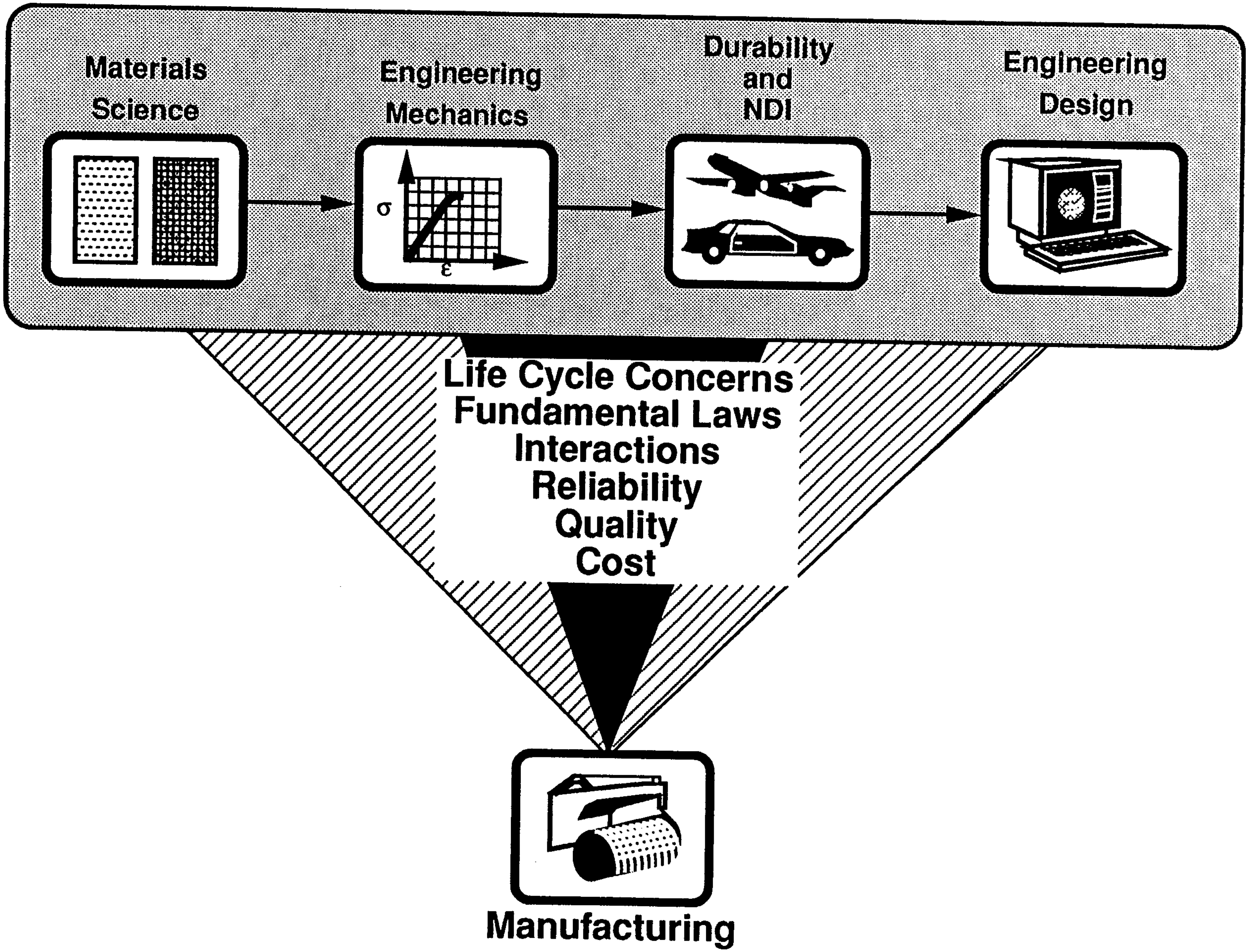
- Definitions
- Differences in Perspective
- Basic and Applied Research
- Inspection, Quality Assurance
- Manufacturing Technology Development
- Evaluation and the Future

MANUFACTURING SCIENCE

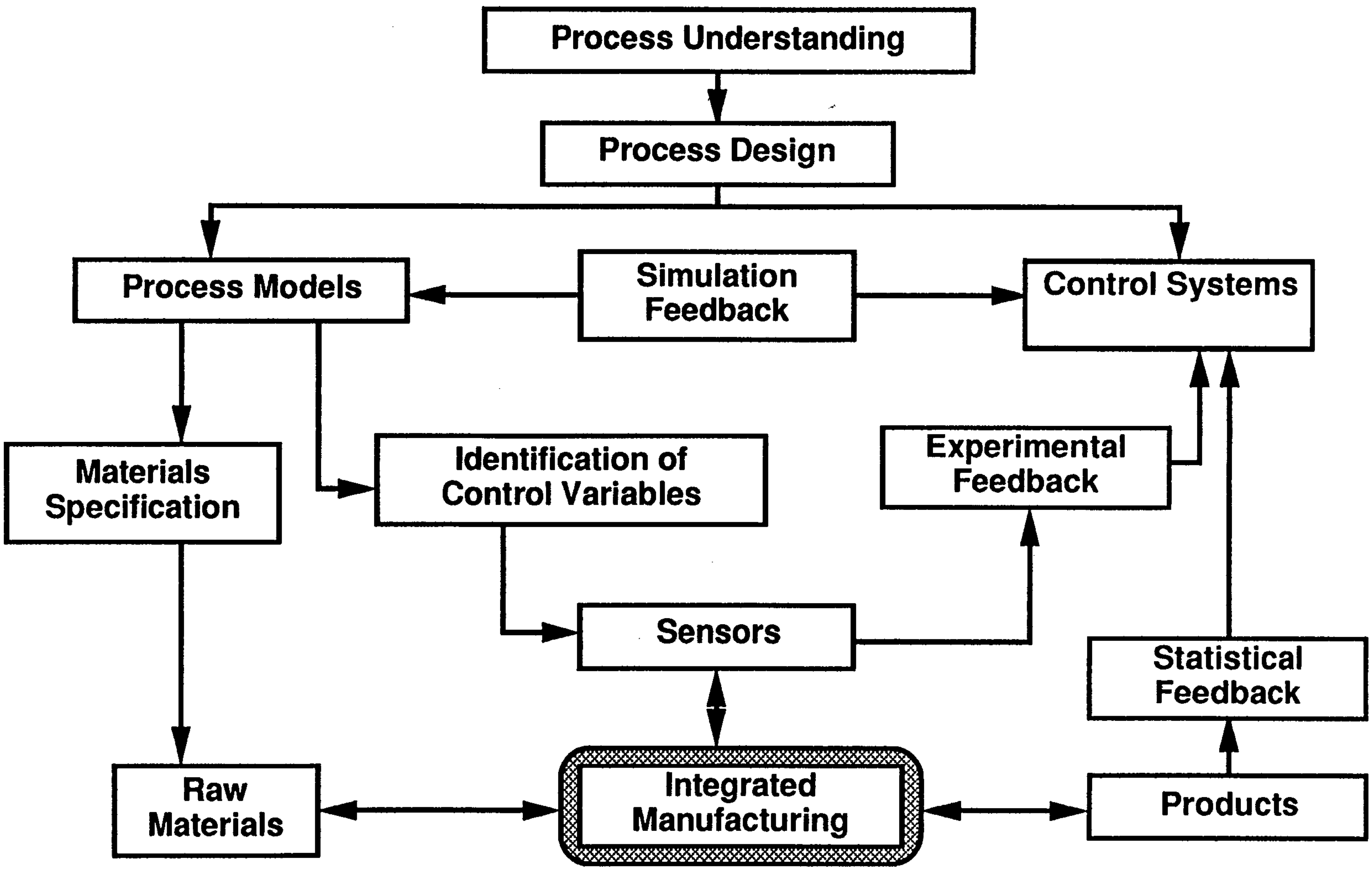
The understanding of the process by which material, labor, energy, and equipment are brought together to produce a product having a greater value than the sum of the individual inputs.



INTERACTION WITH KEY AREAS



INTELLIGENT MANUFACTURING - THE U.S. WAY

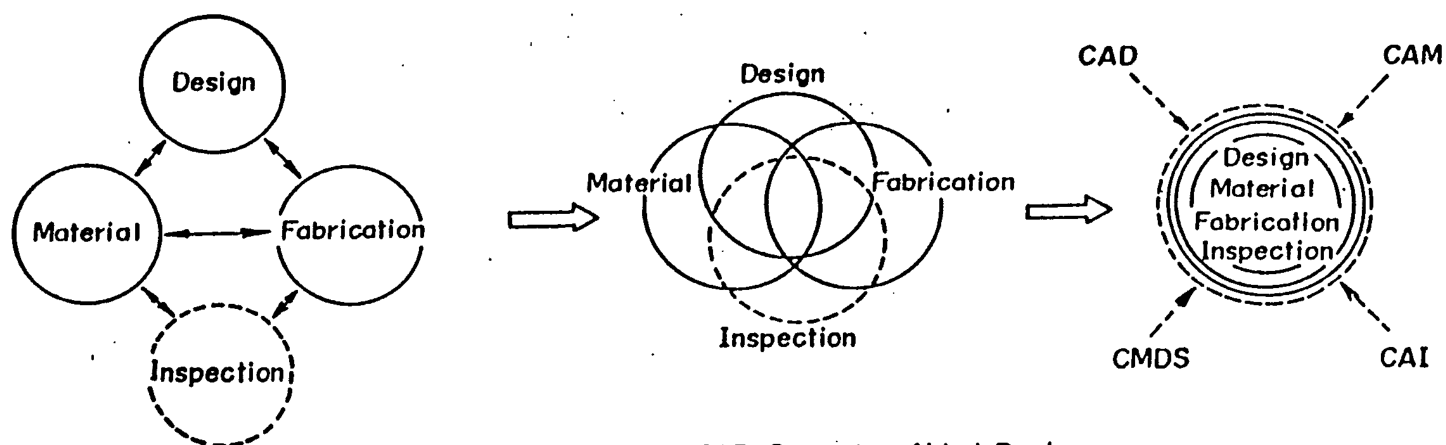


Use of Process Models, Sensors and Controls

IDEALIZED MANUFACTURING SCIENCE SYSTEM

- University of Tokyo

Integration of
- Design
- Materials
- Fabrication
- Inspection



CAD: Computer Aided Design
CAM: Computer Aided Manufacturing
CAI: Computer Aided Inspection
CMDS: Computerized Materials Data System

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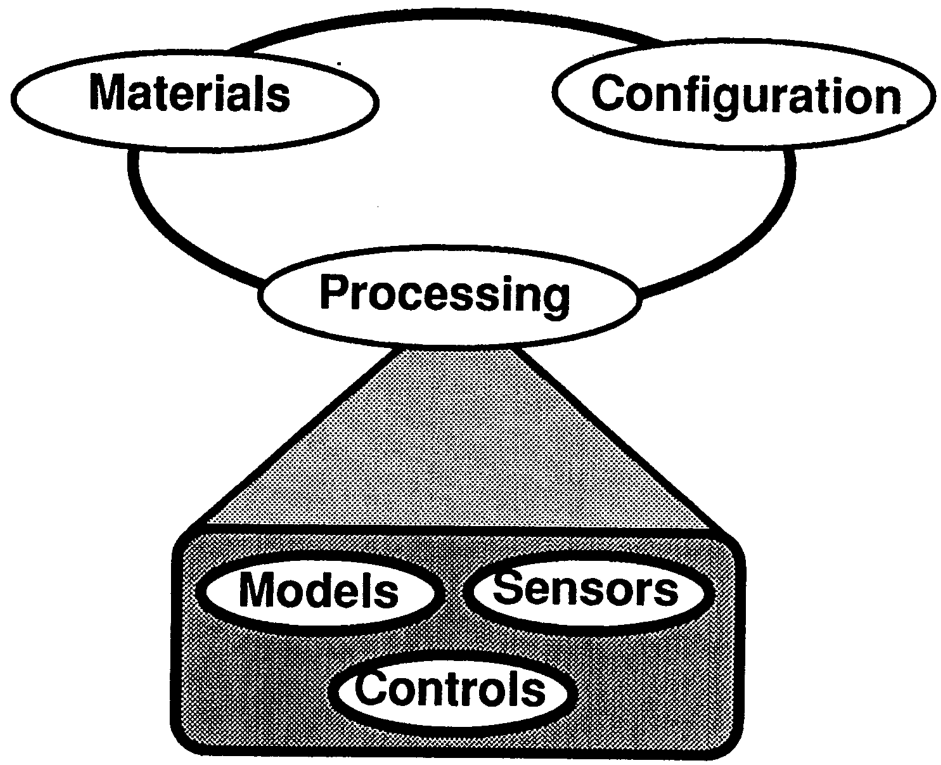
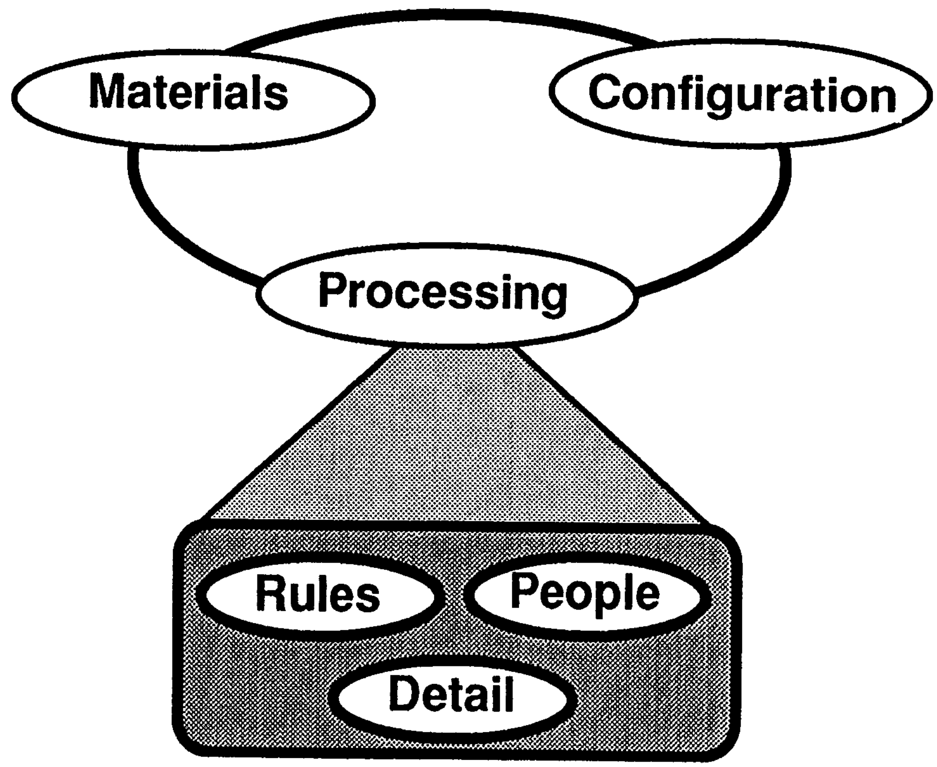
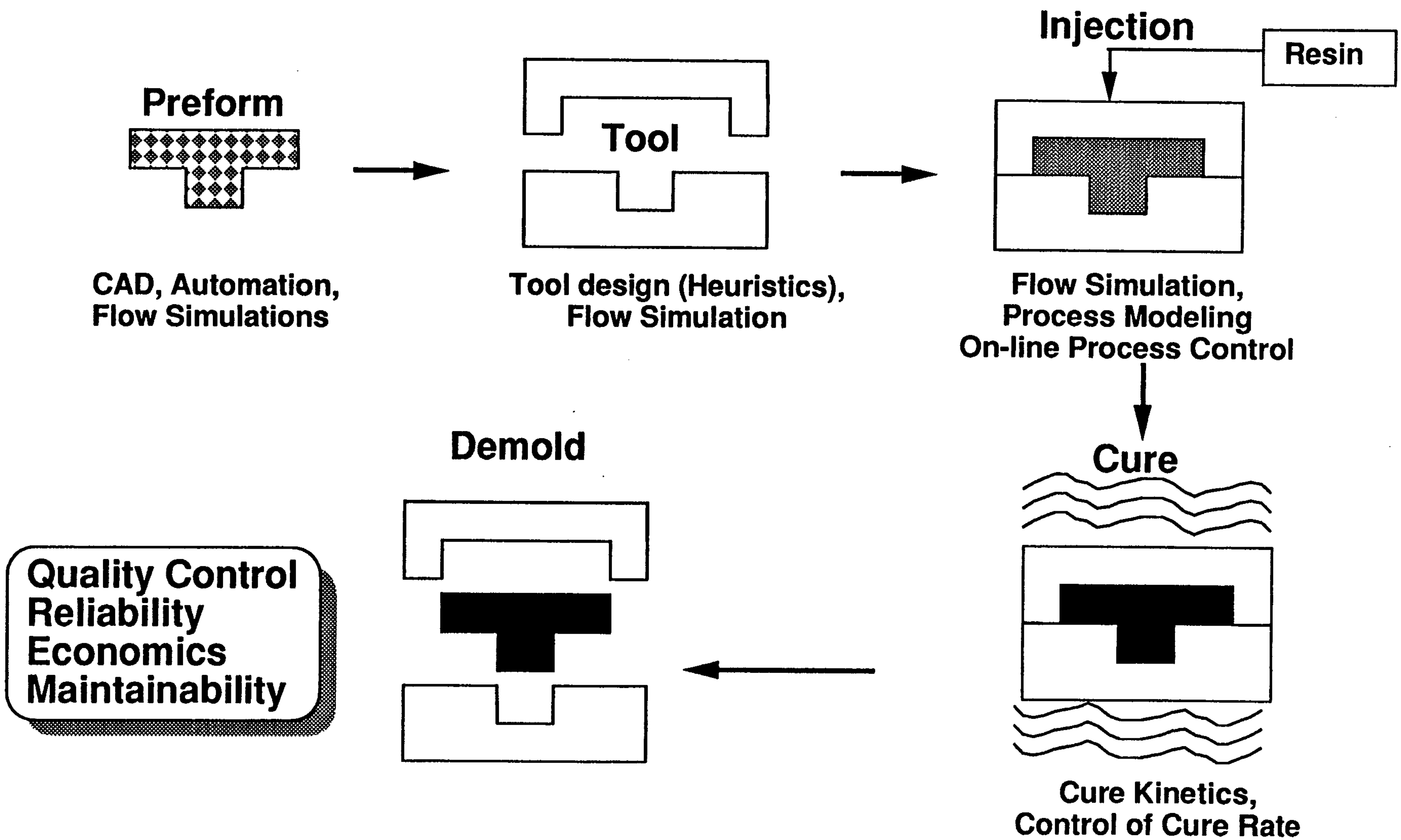
COUPLING OF DESIGN INTERACTIONS FOR INTELLIGENT MANUFACTURING



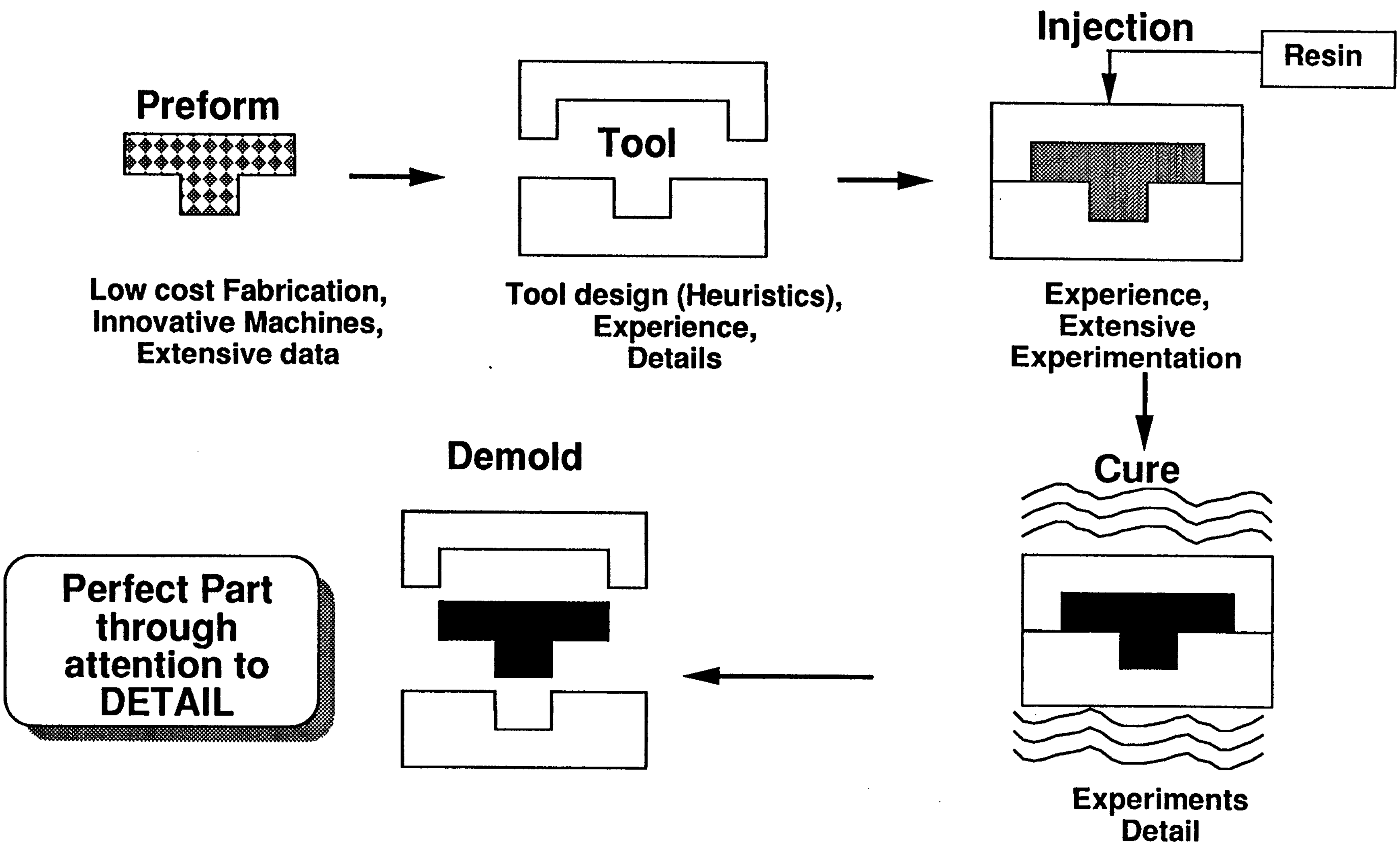
COUPLING OF DESIGN INTERACTIONS FOR INTELLIGENT MANUFACTURING



CONCURRENT ENGINEERING APPLIED TO LIQUID MOLDING



INTRINSIC CONCURRENT ENGINEERING APPLIED TO LIQUID MOLDING

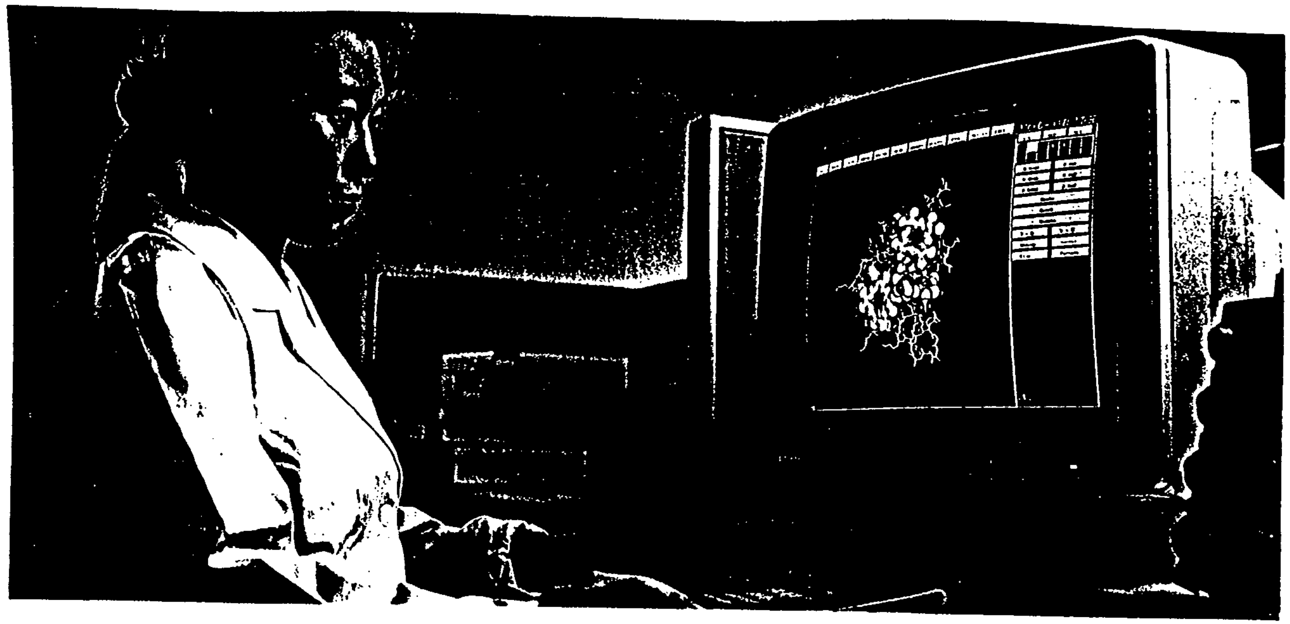


THE JAPANESE APPROACH

- Use of a building block approach
- Extensive experimentation
- Trade-off analysis
- Achievement of in-depth understanding
- Attention to "people factors"
- Attention to detail

MODELLING OF POLYMERIZATION CHEMISTRY

- Mitsui Toatsu Chemicals, Inc.



- Development of new thermoplastic polyimides
- Development of new carbon fiber reinforced thermoplastic composites with high heat resistance levels (supersonic aircraft applications)

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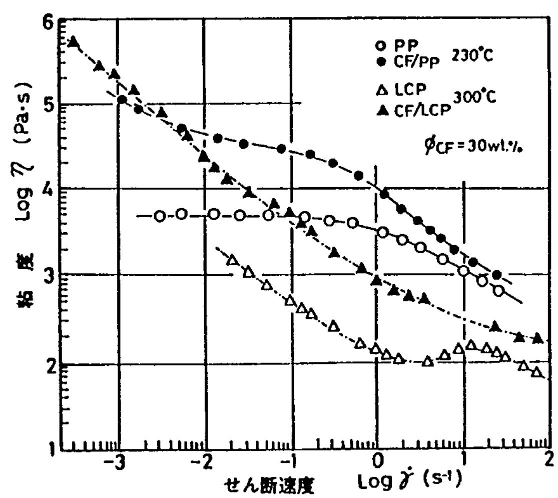
RHEOLOGY OF FILLED POLYMERIC SYSTEMS

- RIPT: MITI

- **Simulation and experiments**
- **Critical mix for thermoplastic composite development**
- **Main factors were fiber length and stiffness effects on viscosity and elasticity**



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POLYMER COMPOSITE RELEVANT STUDIES AT RIPT

- Polymer-metal cluster composites
  - synthesis and characterization
- Reaction control
  - microstructure and surface analysis through analytical techniques
- Synthesis and functionalization of self-organizing polymers
  - determination of relationships between self-organizing monomers and supermolecular structure
- Silicon-based polymers
  - basic technology development

LIMITED USE OF SIMULATIONS

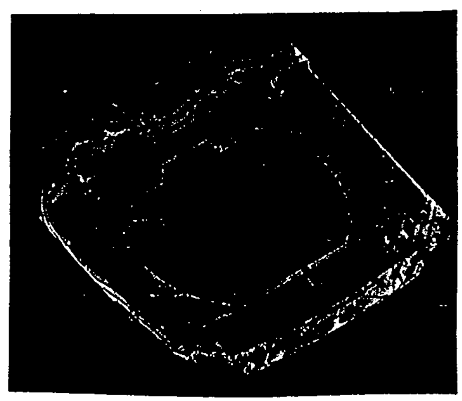
- Nippon Steel

- Fluid Flow / Rheology
- Chemical interactions between fiber and matrix

- Models used for qualitative evaluation
- In-depth experiments are conducted to obtain quantitative values
- Experimental evaluations are often faster and more demonstrative to the customer

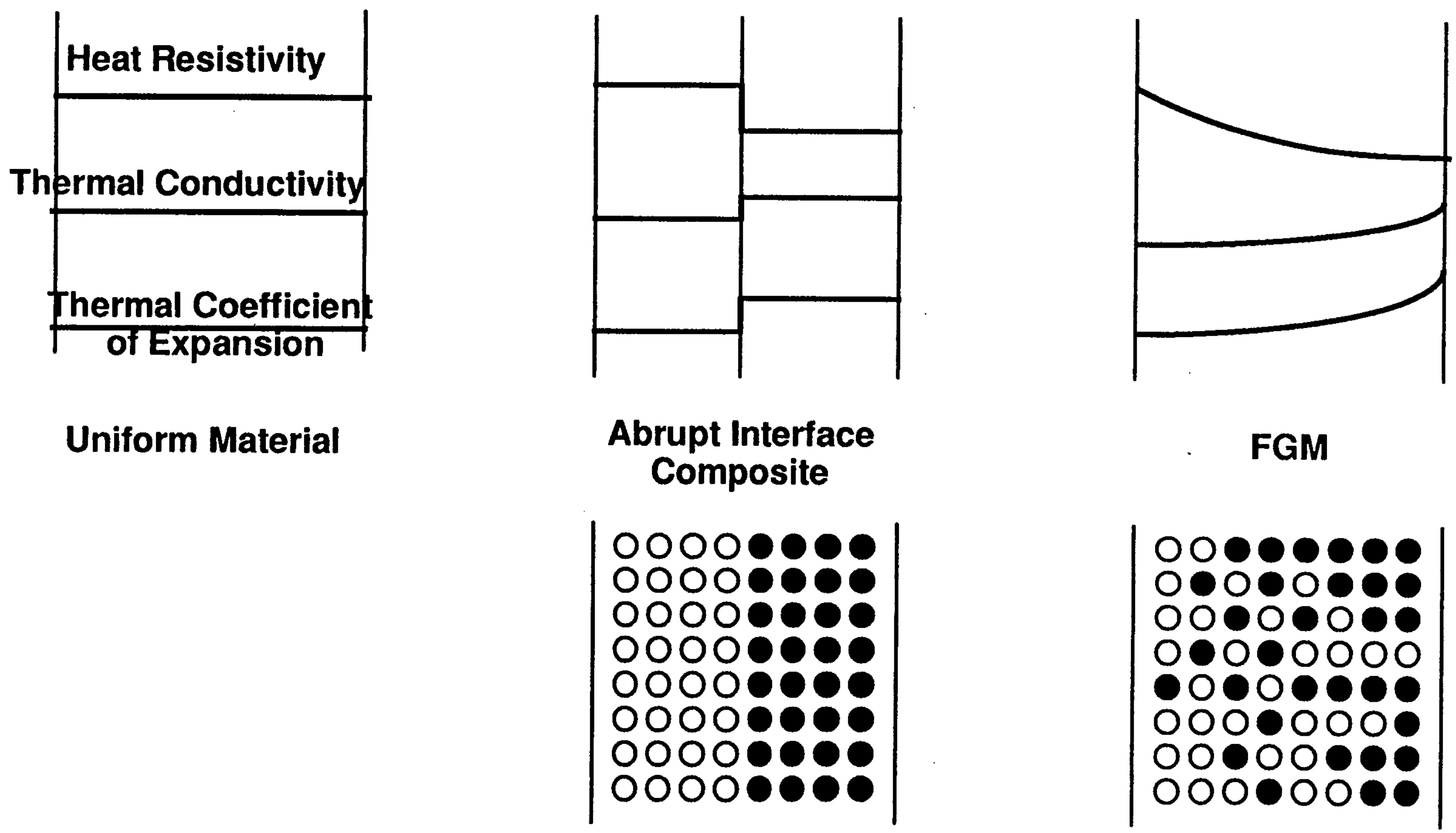
PROCESS SIMULATION

- Mitsubishi Kasei
  - RTM, SRIM
  - Used extensively in a developmental project (Scooter)
  - Code from CCM, University of Delaware
- Mitsui Toatsu Chemicals, Inc.
  - Injection Molding



FUNCTIONALLY GRADIENT COMPOSITES

- Academic and fundamental focus in the US
- Applications driven focus in Japan



FUNCTIONALLY GRADIENT POLYMER COMPOSITES

- RIPT

- **Development of materials with new functions through control of molecular structure**

  - polymer blends
  - controlled distribution of fillers
  - controlled orientation of whiskers and particulates in hybrid composites

0000

FUNCTIONALLY GRADIENT MATERIALS

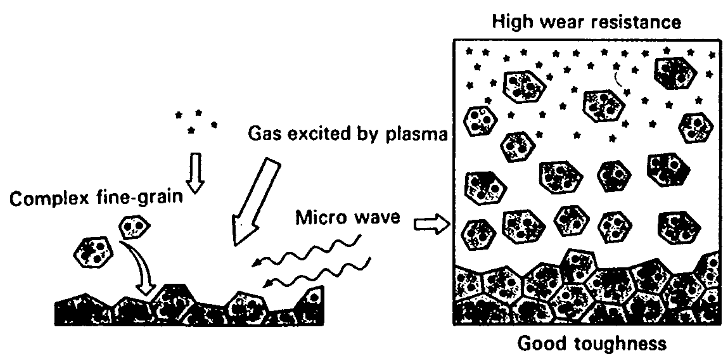
- AIST, MITI

Development of materials processing technology

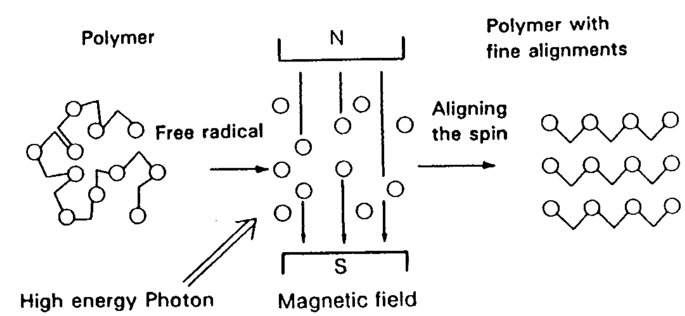
- minute structure and composition control through creation of ultrafine crystals in a reaction field combined with plasma and high speed ions

- advanced reaction fields (including magnetic) to align spin in polymers

Inorganic material processings



Polymer preparation by photo-chemical processing



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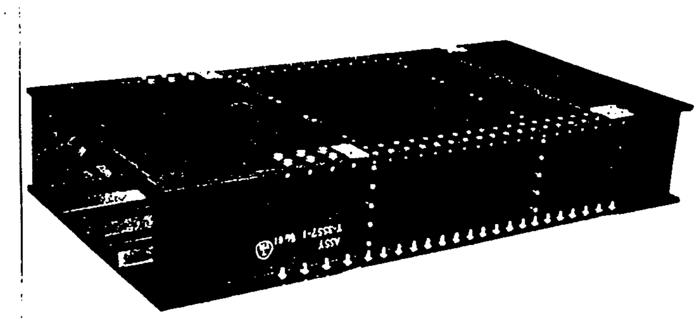
QUALITY CONTROL

- Tests on large components
- Statistical Analysis
- Development of NDI Techniques
- Attention to Detail
- Planning for human factors

WING BOX MODEL



- Fabrication at different companies
- Testing at NAL
- Development using a building block approach (7 year project)

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NON-DESTRUCTIVE EVALUATION SYSTEMS

- NAL

- Damage Assessment
- Process-induced defect determination
- Image enhancement
- Computer control through CAD

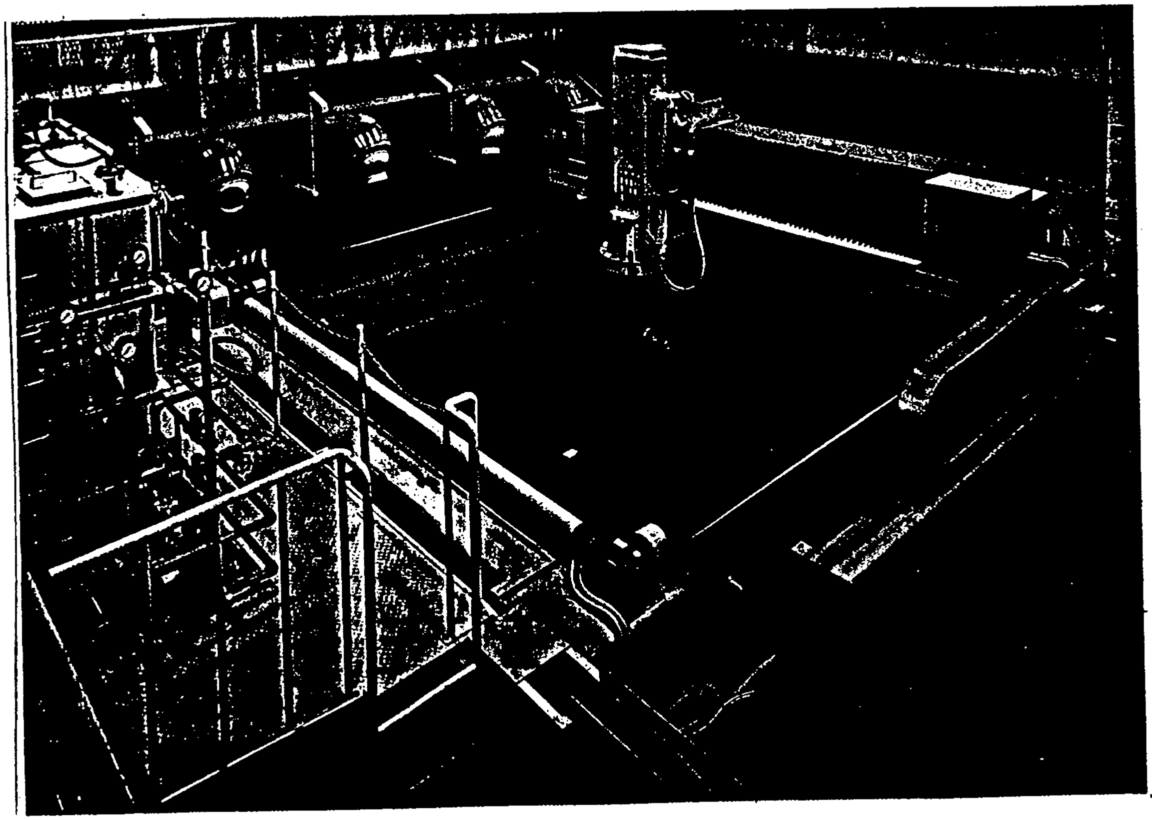
Ultrasonic scanning

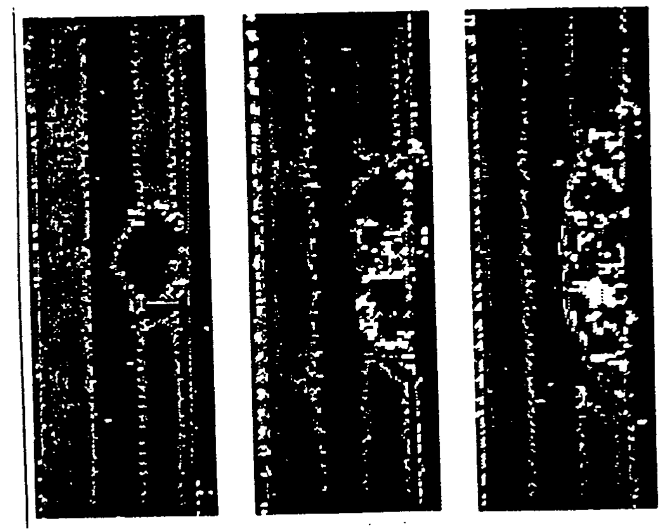
Thermo-mechanical stress analysis

Acoustic Emission Analysis

X-Ray CT Scans

ULTRASONIC SCANNING





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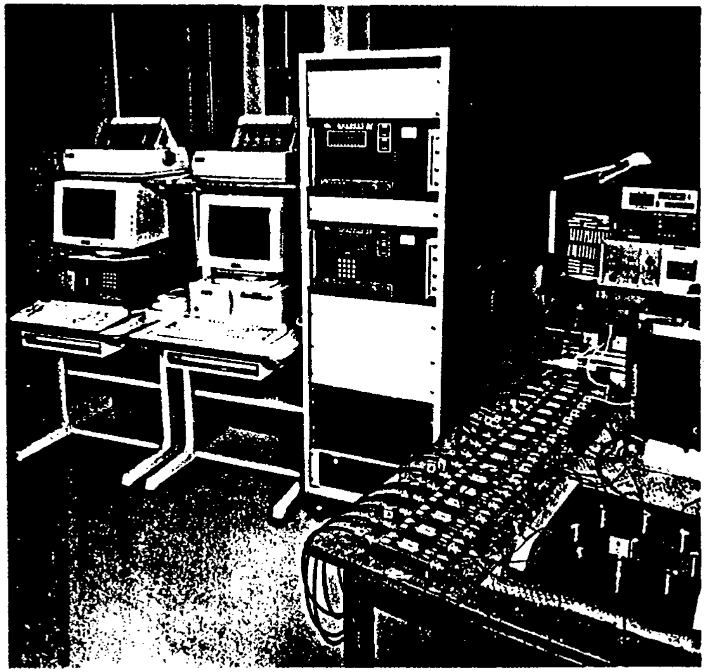
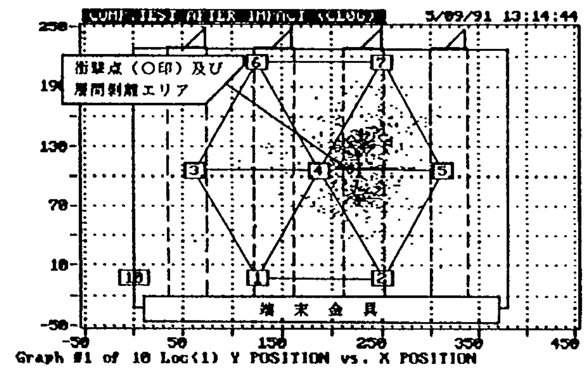
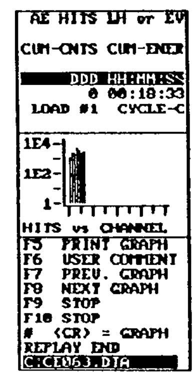
MULTI-CHANNEL ACOUSTIC EMISSION ANALYZER





結果10
ＣＦＲＰ補強平板の衝撃後圧縮試験時のＡＥ源位置標定結果
（赤点がＡＥ源位置）
Results of AE Location Identification for Compression Test of CFRP Stiffened Panels.
(Red dots : AE Source)



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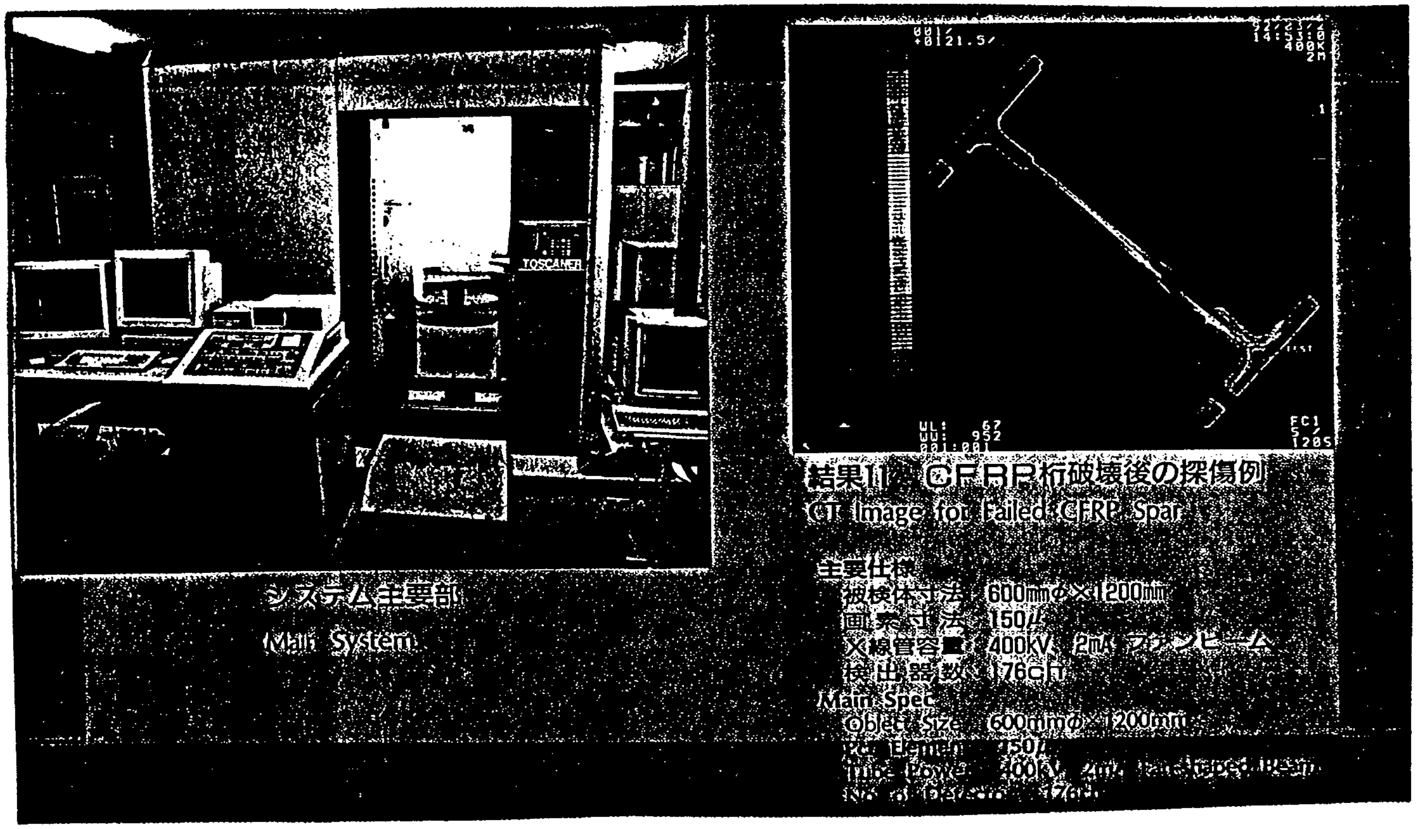
X-RAY CT SCANNER



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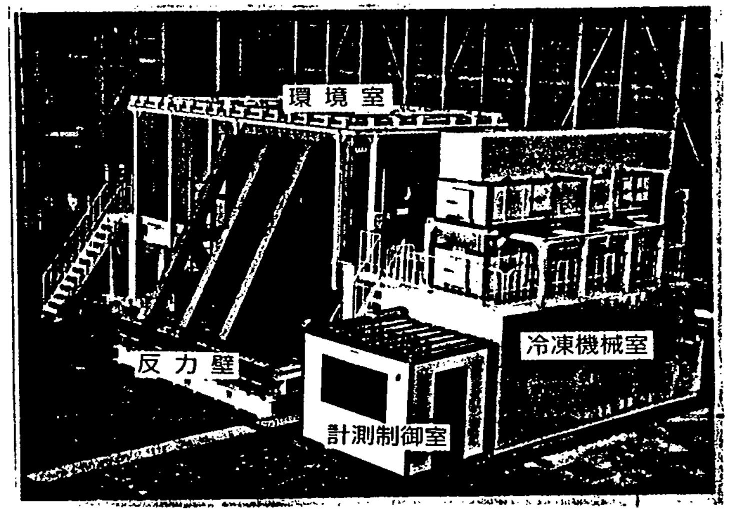
LARGE SIZE ENVIRONMENTAL CHAMBER



- 9m x 5m x 3m
- -70°C to 200°C
- Maximum of 350°C on a surface
- Upto 95% RH

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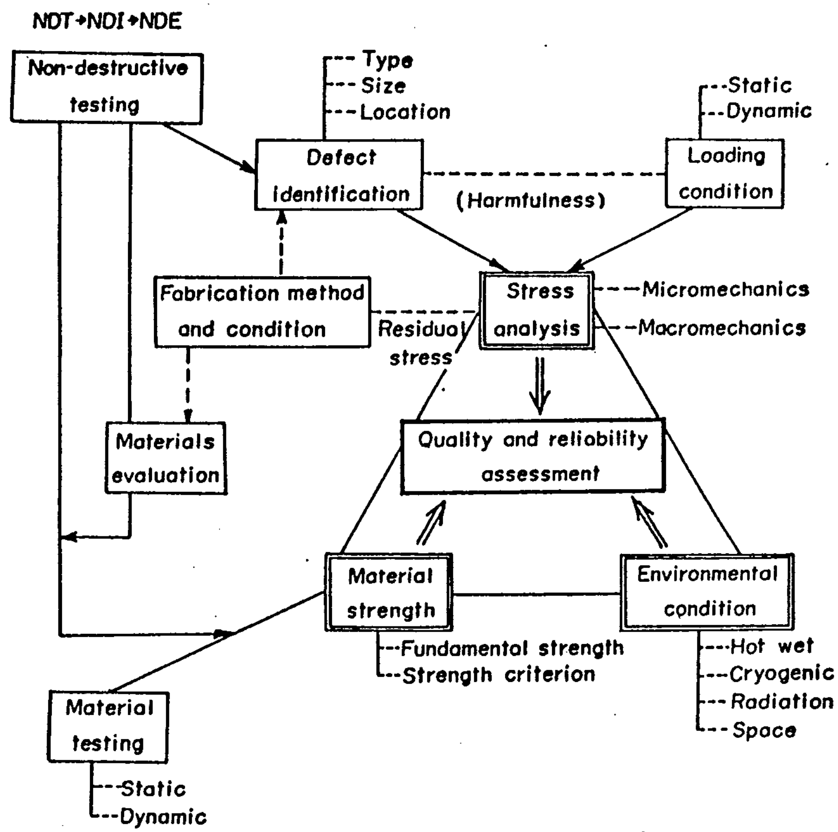
QUALITY AND RELIABILITY ASSESSMENT

- University of Tokyo



NDT: Non-destructive testing
NDT: Non-destructive inspection
NDE: Non-destructive evaluation

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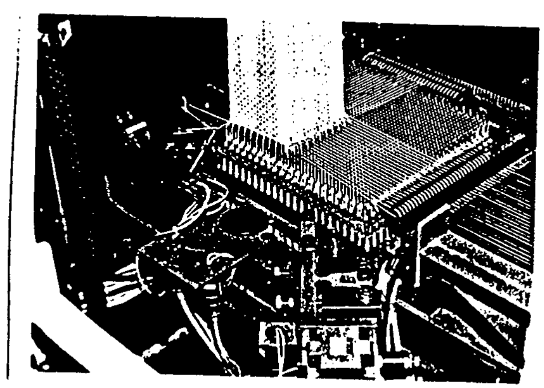
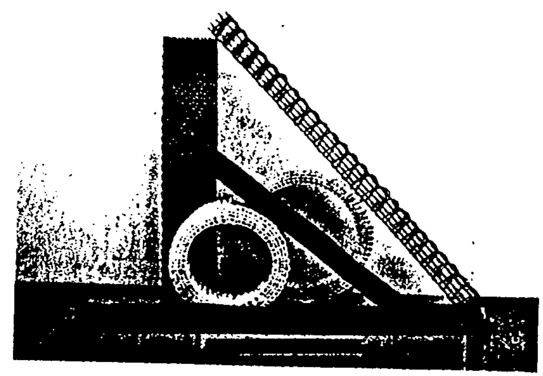
DEVELOPMENT OF 3D BRAIDING TECHNIQUES

- T. Kitano, RIPT

- Development of automated computer controlled looms for block-type and dome shaped 3D construction (including hollow structures)
- Hybrid constructions
- Cheaper and faster





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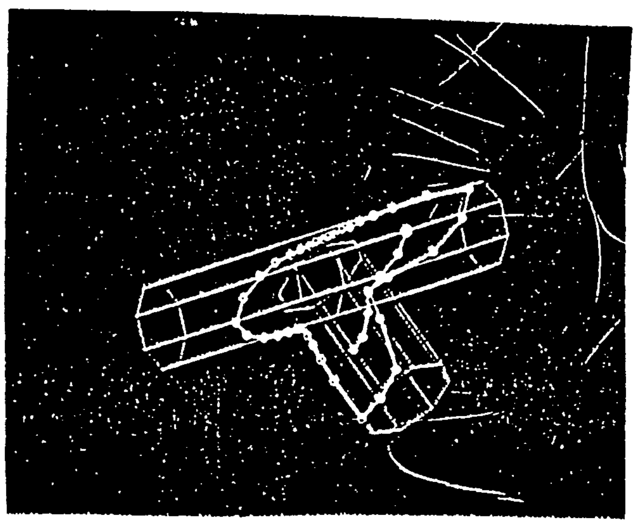
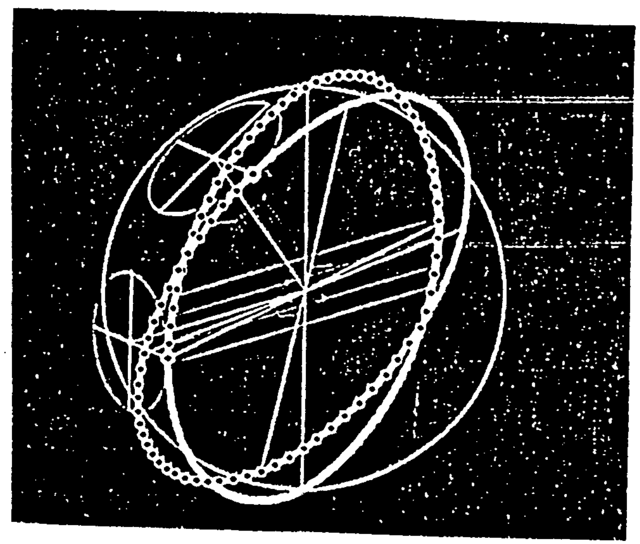
SIMULATION OF 3D BRAIDING OPERATIONS

- Z. Maekawa, Kyoto Institute of Technology

- Very difficult to visualize
- First step towards tailoring architectures





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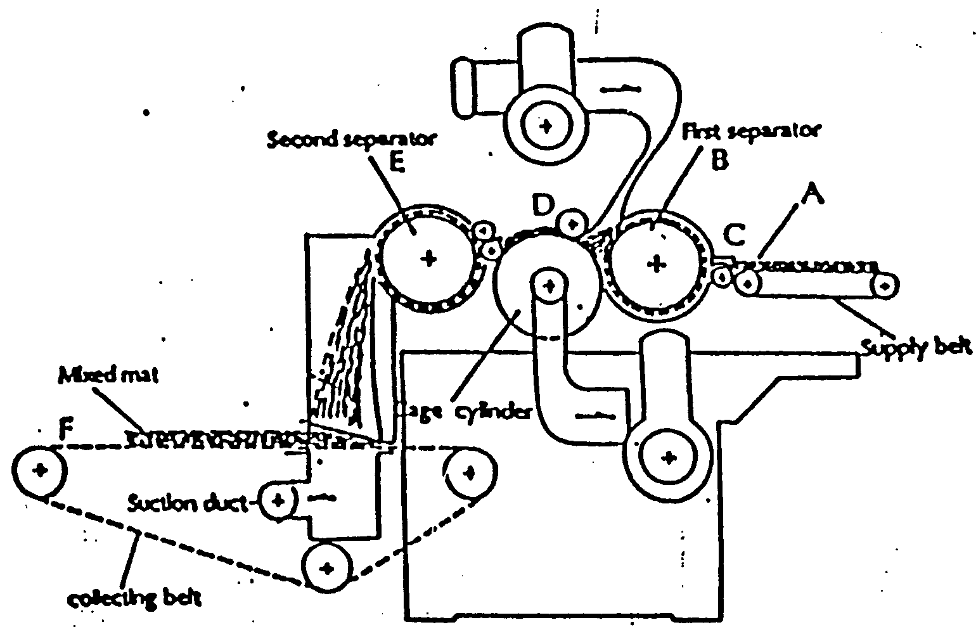
PRODUCTION OF MIXED THERMOPLASTIC MATS

- T. Kitano, RIPT

- Cheap production of stampable mats
- Hybrid - glass and carbon fiber
- Polyamide fiber yarn (Nylon 6, PA) as a matrix
- Application to functionally gradient materials



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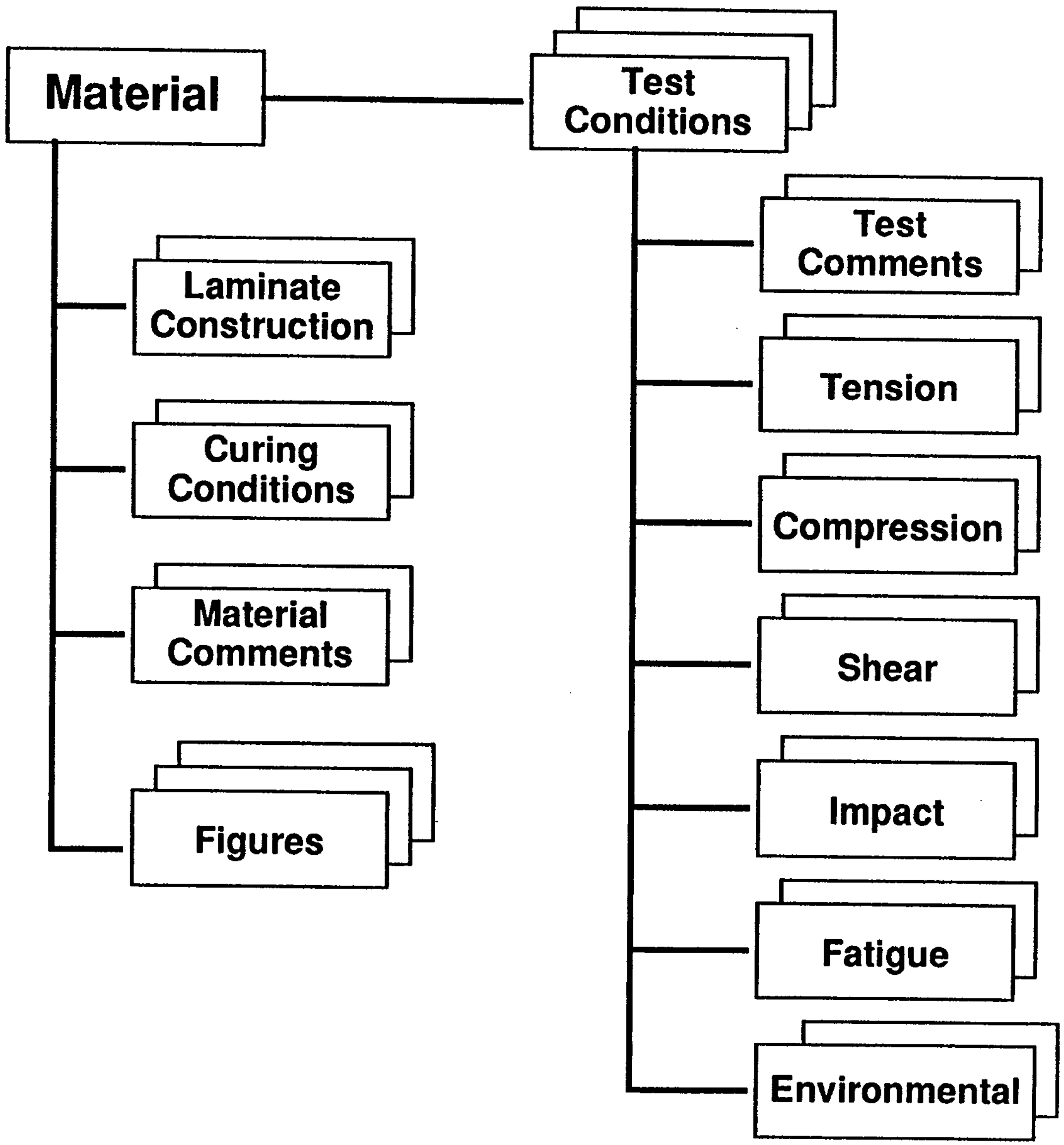
CO-CURING TECHNOLOGY

Generally rated as better than the best U.S. capability

5 steps to co-curing technology (per MHI):

- Determination of applicable range of co-curing, and design/manufacturing/QA tradeoffs for each part (resource maximization, zero scrap, no bag leaks)
- Check performance of co-cured interface in tension, peel stress and in-plane shear
- Use FEA to design parts for minimal thermal deformation
- Design for achievable tolerances in production
- Develop effective repair techniques
- Pay attention to detail during hot compaction and post-compaction NDI

PRODACOM



Property Database for Advanced Composite Materials

- MITI Project
- Hierarchical structure
- Currently > 20,000 entries (1 entry = 1 test)

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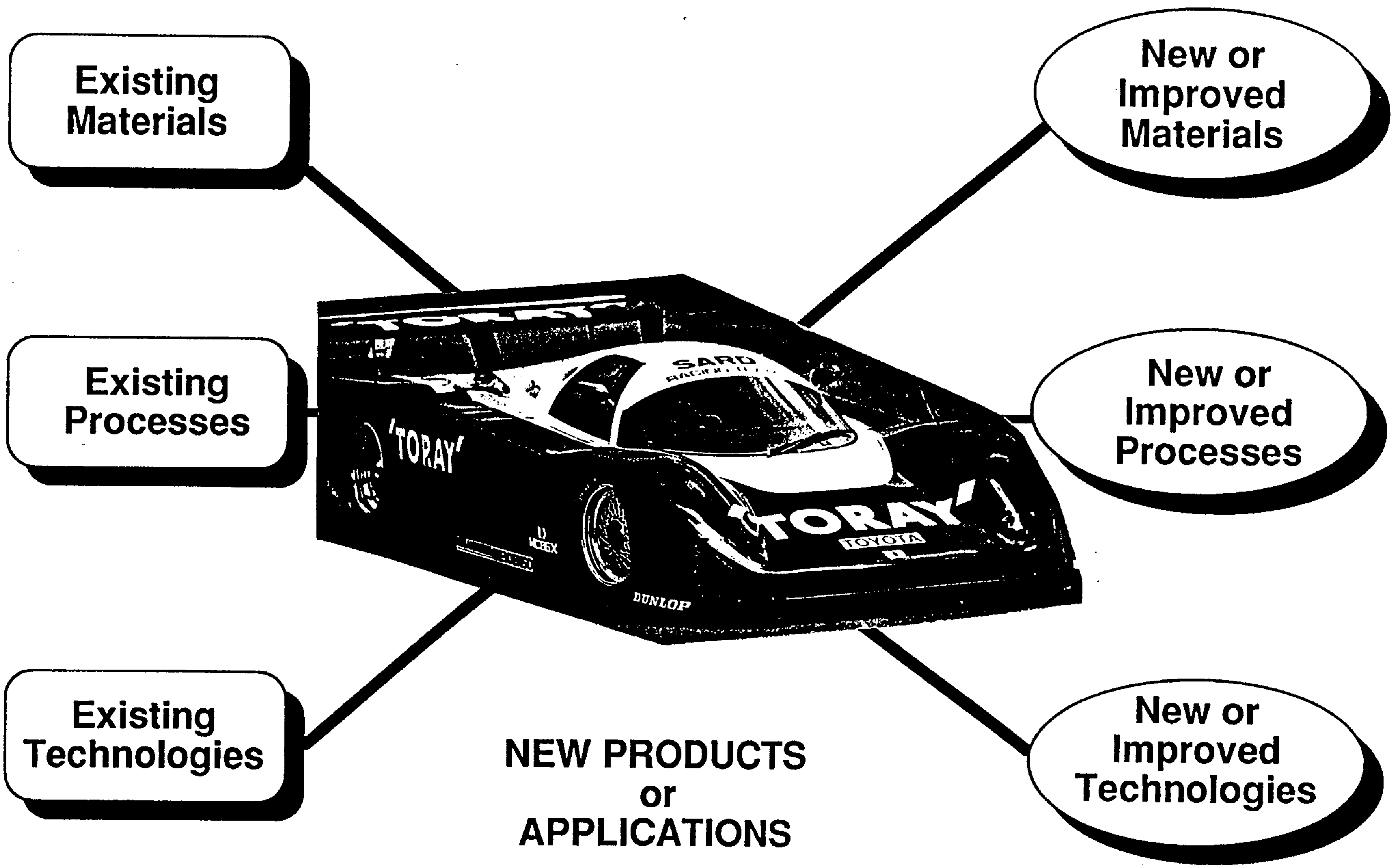
EVALUATION OF JAPANESE INDUSTRIAL TECHNOLOGY

As per MITI's assessment

- Conventional industrial products manufactured in Japan are technologically equal or superior to comparable products throughout the world
- Technological level of Japan's high-tech products is always improving with a considerable number meeting or surpassing the world standard
- Level of basic technology research is generally lower than that for manufactured goods, both conventional and high-tech.

FOCUS



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CONCLUSIONS

- People factors, extensive testing and attention to detail are the keys
- Assiduous effort to perfect fabrication processes
- Upfront effort and concurrent engineering to prevent downstream problems
- Detailed and superior production area management
- Long range planning and individual honor

Improve things that work and change those that don't

Change must start at the top

We can be the world's best

PRODUCT AND PROCESS DEVELOPMENT METHODS

Vistasp M. Karbhari
Center for Composite Materials
University of Delaware

JTEC Summary: Product and Process Development Methods
Vistasp M. Karbhari
February 16, 1993

In an effort to expand the applications for polymer composite structures, the United States government convened a panel to evaluate the status and outlook for manufacturing technology in the U. S. and Japan, with an eye toward finding or developing mechanisms of cooperation. A 10-person team visited approximately 20 Japanese organizations over a 10-day period in December 1992. This summary provides an overview of product and process development; a full report, to be completed later in 1993, will include detailed conclusions.

Because design decisions for composites are coupled—necessitating simultaneous consideration of materials, configuration, and process plan—early decisions take on increased criticality. Keys to the development of production systems include quality, cost, delivery, and flexibility. In Japan, these goals are met through functional integration—multi-functional teams are used routinely, administration not only coordinates but also champions goals, the existing knowledge base is given to new team members, and knowledge is integrated by a core group very early in the process. Negative effects are planned for, including such issues as recycling, styrene emissions, and fire resistance. Long-term solutions are sought and multiple production methods used. Tremendous emphasis is placed on the human role in production.

The Japanese have identified five emerging "techno-paradigm" shifts: (1) manufacturing companies—from producing to thinking organizations; (2) business dynamics—from single to multiple-technology base (diversification); (3) R&D activities—from visible to invisible enemies (competition from other industries rather than from industries within the same industrial sector); (4) technology development—from a linear to a demand articulation process (a focus on how to put existing technology to the best possible use); and (5) technology diffusion—from technical to institutional innovation.

Manufacturing 21 is the first in a set of industry-led five-year initiatives aimed at charting the future of Japanese manufacturing. The university-industry collaborative program focuses on the competitive advantages of TQM and JIT, global markets and competition, and the need for a future agenda and vision. The objectives are to develop flexible manufacturing, to make human resource management decentralized and interactive, to integrate through software, to develop appropriate materials and manufacturing techniques, and to attract the best and brightest youth into manufacturing. In the long term, the international vision of the Manufacturing 21 initiative is to search for new markets, new partners, and increased collaboration.

The team drew the following overall conclusions concerning product and process development in Japan:

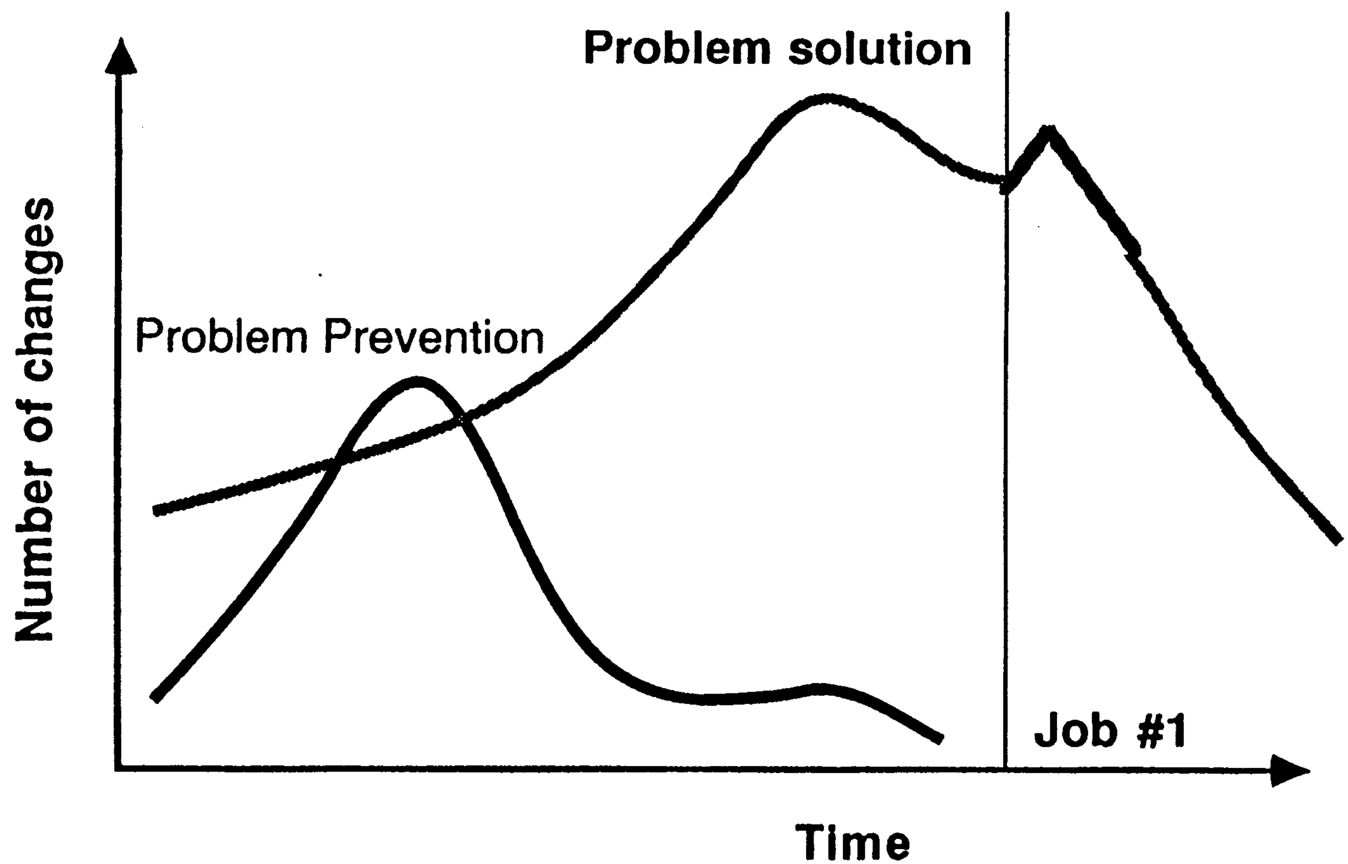
- Japanese product and process development use concurrent engineering by definition. Japanese teams have developed the human factors issues far beyond those in the West.
- Longer development lead times for projects are allowed in Japan than in the U. S., and investigators are given greater latitude and confidence for long-term gains.
- Products are often highlighted through demonstration projects.
- Materials development is applications driven.
- The product/process realization team is committed at an individual level to the project and works together with full management backing.

The management philosophy of Nippon Steel perhaps best sums up the Japanese approach to manufacturing: *Like a great river, flowing steadily but changing constantly, the history and work of Nippon Steel are a matter of both tradition and transition.*

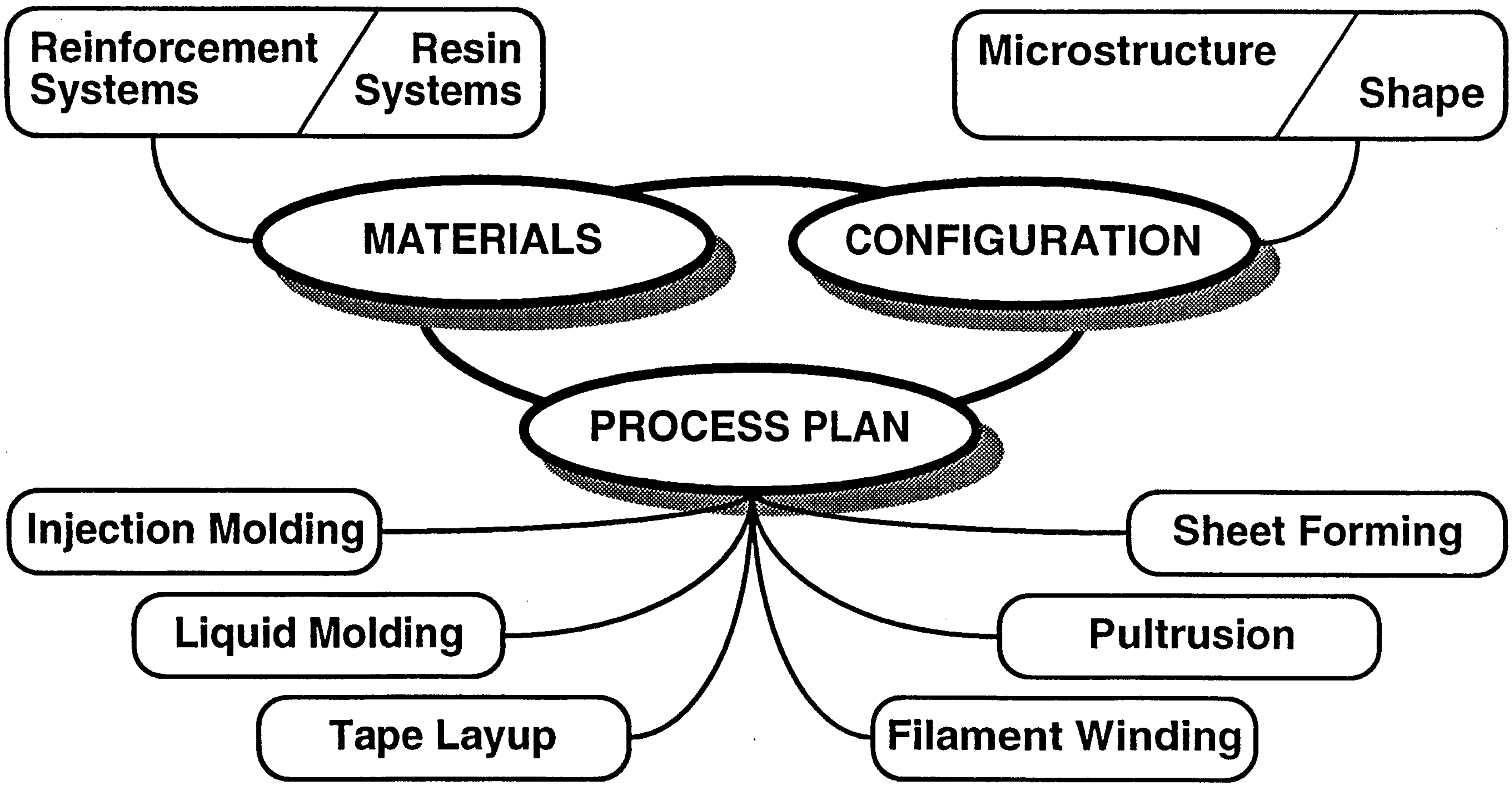
OUTLINE

- Motivation
- Keys to the Development of Production Systems
- Short Case Studies
  - New Materials
  - New Material Forms
  - Integrated Process Development
  - New Product Development
  - Focussed Planning
- R&D Focus - Management Structure
- Planning for the Future
- Conclusions

THE INFAMOUS DOUBLE HUMPED CURVE



DESIGN DECISIONS FOR COMPOSITES ARE COUPLED



KEYS TO THE DEVELOPMENT OF PRODUCTION SYSTEMS

QUALITY

COST

DELIVERY

FLEXIBILITY

ROLE OF MITI
(as seen by companies)

- Catalyst for IR&D funding
- Team building for pre-competitive technology development
- Focus on critical technologies
- Foreign collaboration

MITI PROJECTS

- Large, long-term projects which integrate leading companies
- Very few small companies or set-asides
- Focussed vision to provide impetus
- Foreign collaboration almost a necessity (Companies, Universities)
- Reporting procedures are easy and quick
- Technology dissemination is critical

FUNCTIONAL INTEGRATION

- Routine use of multi-functional teams
- Administration goes beyond coordination
  - Championship of goals
  - Shift to HQ (Yamaha)
- Negotiation with sections/leaders
- Knowledge base given to new "team members"
- Group enthusiasm and ownership
- Integration of knowledge by a core group very early in the process

NEGATIVE EFFECTS TO BE PLANNED FOR

- Side-effects must be predicted
- They must not be neglected - but must be tackled early in development
  - Recycling and composites (Honda, Toyota)
  - Styrene emmissions (Yamaha)
  - Fire resistance (Shimizu)
  - Braided connections for tubes (Sumitomo Precision Products Co.)
- Parallel routes
  Use of multiple production methods (Mizuno)
- Search for long term solutions

USE OF HIGH-FOCUS BENCHMARKS

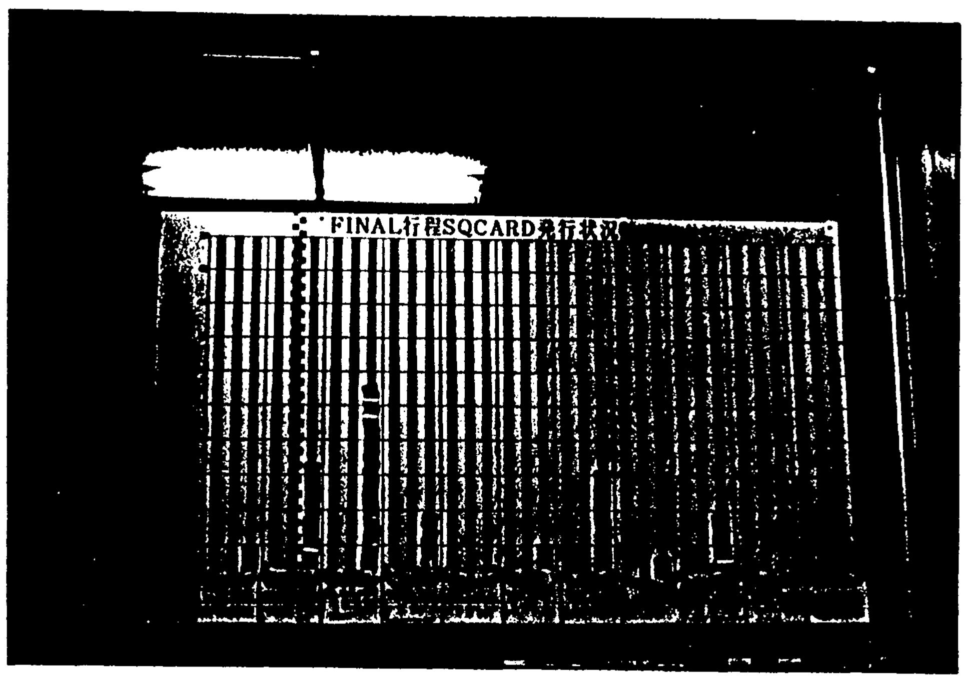
- Product line launcehed with a flash - not necessarily through similar products
- Use of "new" concepts to sell old ideas
    - Human powered boats
    - Solar powered boats
- Showcase for technology (Buildings)
- Products way ahead of market

EMPHASIS ON THE HUMAN ROLE

- People cannot be replaced by machines even in the ultimate projection of CIM
  - attention to detail (JAMCO)
- Best use of human capabilities
  - energy, committment
  - honor
- Primary human work (direct people interaction) cannot be automated. Secondary (maintenance, inspection) work must be
  - emphasis on NDE

USE OF "ERROR" CHARTS

- Listing of different sections involved in a project
- Errors made by each section are marked daily
- Status is reviewed by team members
- Error is fixed at source (education, change in material, change in methodology, change in approach)
- No "finger-pointing"



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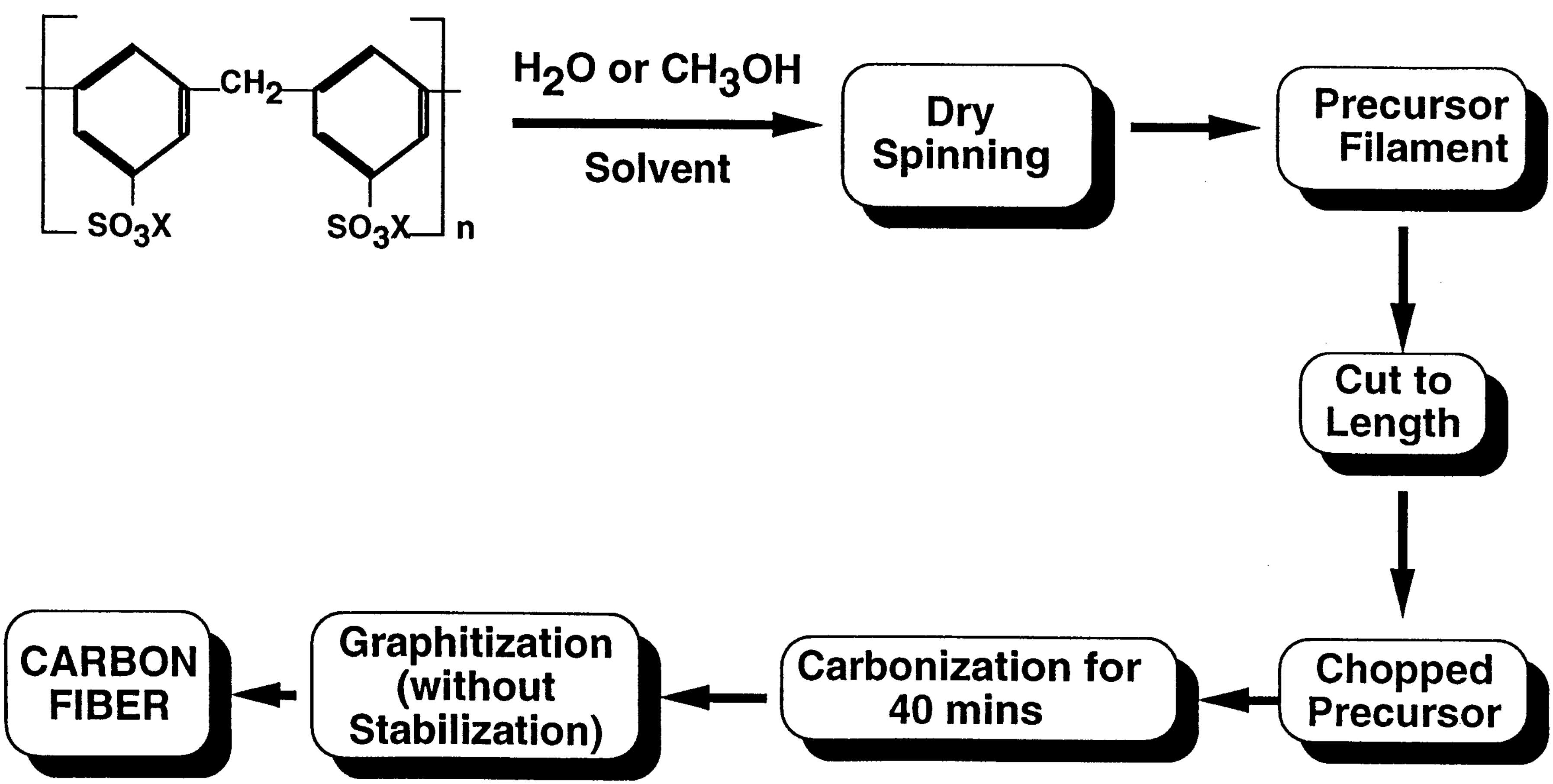
DEVELOPMENT OF NEW MATERIALS

Need for

- Cheaper Carbon Fiber
- Affinity to Concrete Slurry

The development of a potential market served as the impetus for the development of new forms of reinforcement as well as a new form of carbon fiber (Mitsui Mining Company Ltd.)

PROCESS USED IN DEVELOPMENT OF NEW FORM



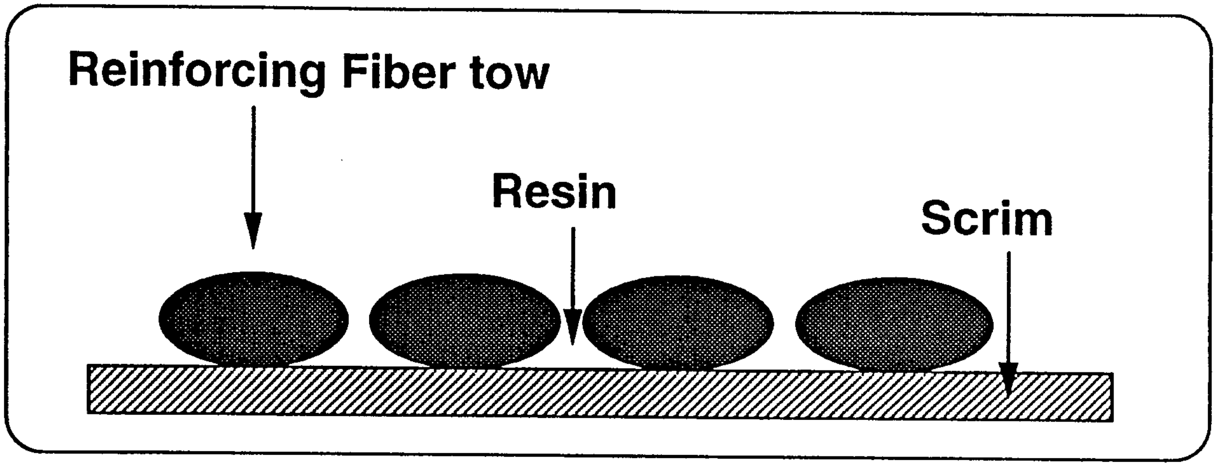
DETAILS

Diameter	16-20μm
Tensile Strength	113-128 ksi
Tensile Modulus	4.7 - 5.4 Msi
Density	0.06 lbs/in^3 (1.6 gms/cm^3)

- Strong affinity for slurry (hydrophillic)
- No stabilization during pyrolysis
- Potential for low cost fiber
  - low cost precursor
  - low cost solvent
  - low cost pyrolysis

DEVELOPMENT OF MATERIAL FORM

FORCA tow sheet - TONEN

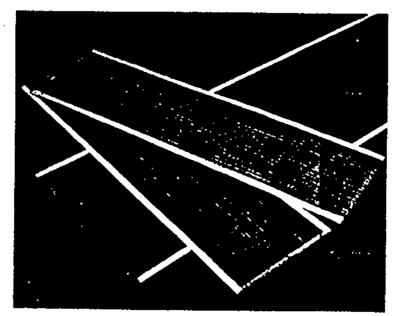


Specific form and process was developed for easy application to structures

- Liquid crystalline petroleum pitch precursor
- 10 micron diameter filaments
- Tensile strength 3300 MPa (470 ksi)
- Tensile modulus 700 Gpa (100 Msi)

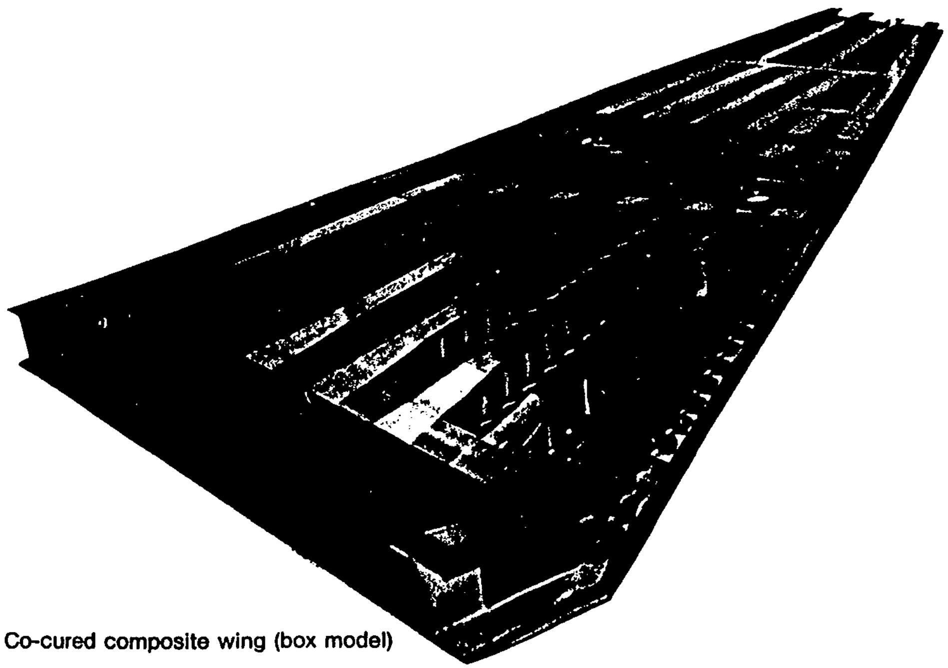
FORCA TOW SHEET

- Pre-existing materials capability
- Pre-existing materials form (prepreg)
- Identification of new market (infrastructure rehabilitation)
- Identification of current materials drawbacks (applicability and ease of use)
- Development of new form of existing material (tow sheet)



INTEGRATED MATERIALS, PROCESS AND PRODUCT DEVELOPMENT

- Wing box
- Collaboration between aircraft companies, resin manufacturer and NAL
- Development of resin, co-curing techniques, NDI techniques



Co-cured composite wing (box model)

Mitsubishi Heavy Industries, Inc.

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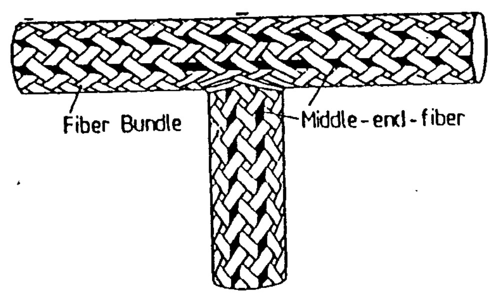
DEVELOPMENT OF A NEW PRODUCT

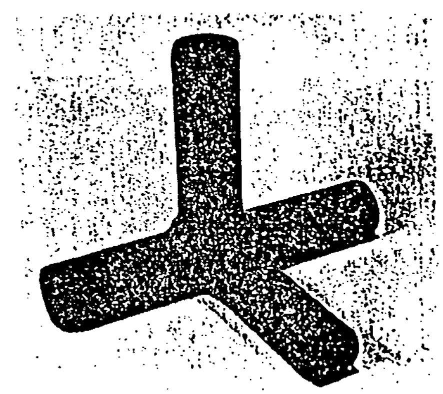
- Composite trusses are more effective than metallic- yet invariably fail at joints
- Composite tube/profile joining is a problem
- Conventional connections are based on steel design
- Need for innovative solutions
  - Materials
  - Fiber architecture
  - Easy processing methods
- Braiding offers a possible solution

JOINING OF TRUSS ELEMENTS

(Sumitomo Precision Products Co. Ltd., Kyoto Inst. of Technology)

- Use of braiding techniques
- Hybrid structures (carbon-glass)
- Multiple-member connections





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DEVELOPMENT OF A NEW PRODUCT (NICHE MARKET)

- Identification of a need
  - small fields
  - use of pesticides
- Suggested solution - small remote control helicopter
- Identification and development by a non-aerospace company as an offshoot of present business (Boats)
- Development through combined IR&D and government funding
- Transition to full scale development quickly
- Small team lead by a champion (Horiuchi)

REMOTE CONTROL HELICOPTER (R-50) - YAMAHA

- Fuselage - 2655 mm
- Main Rotor - 3070mm diameter
- 98 cc engine
- Total Weight 67 kg

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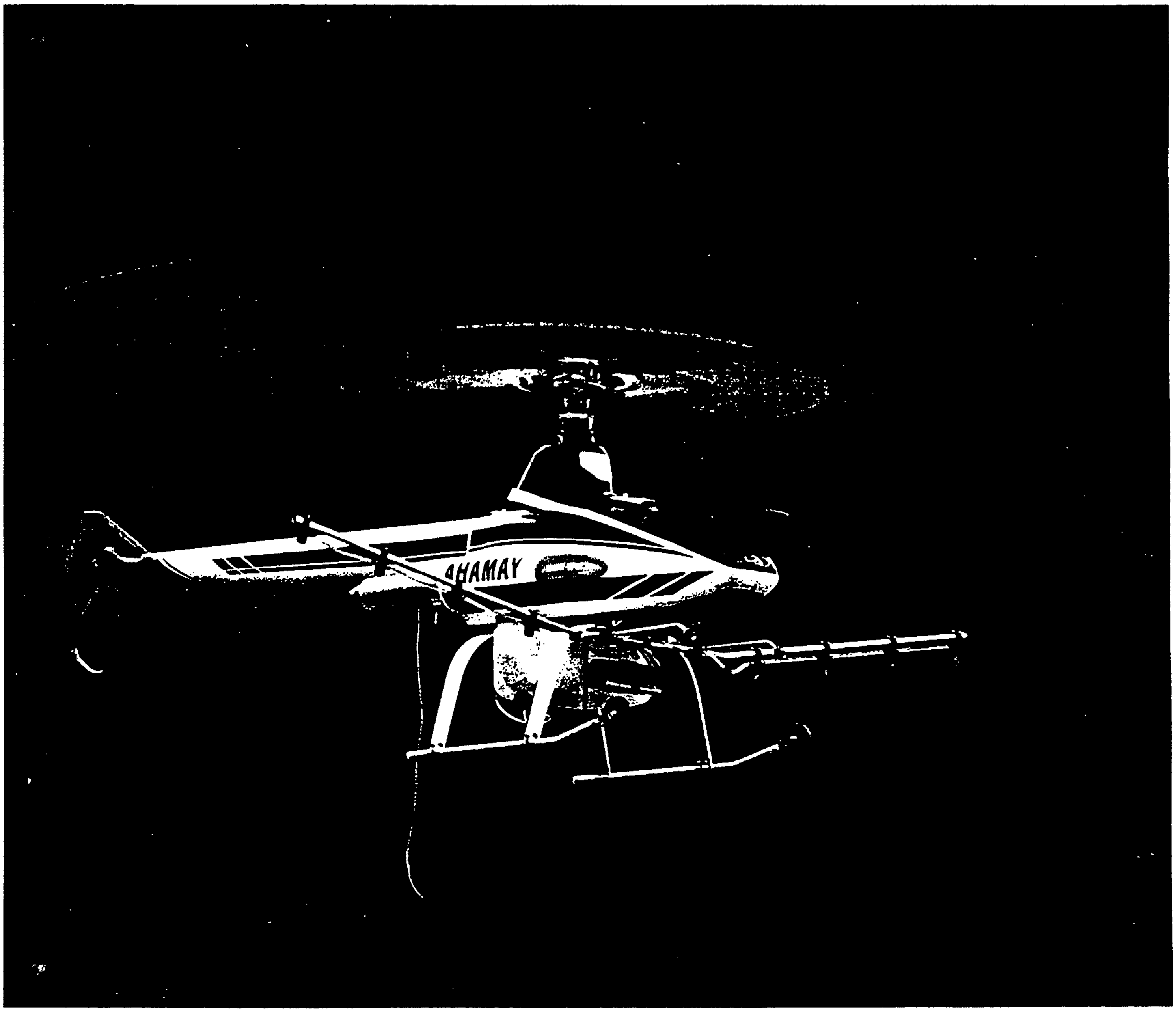
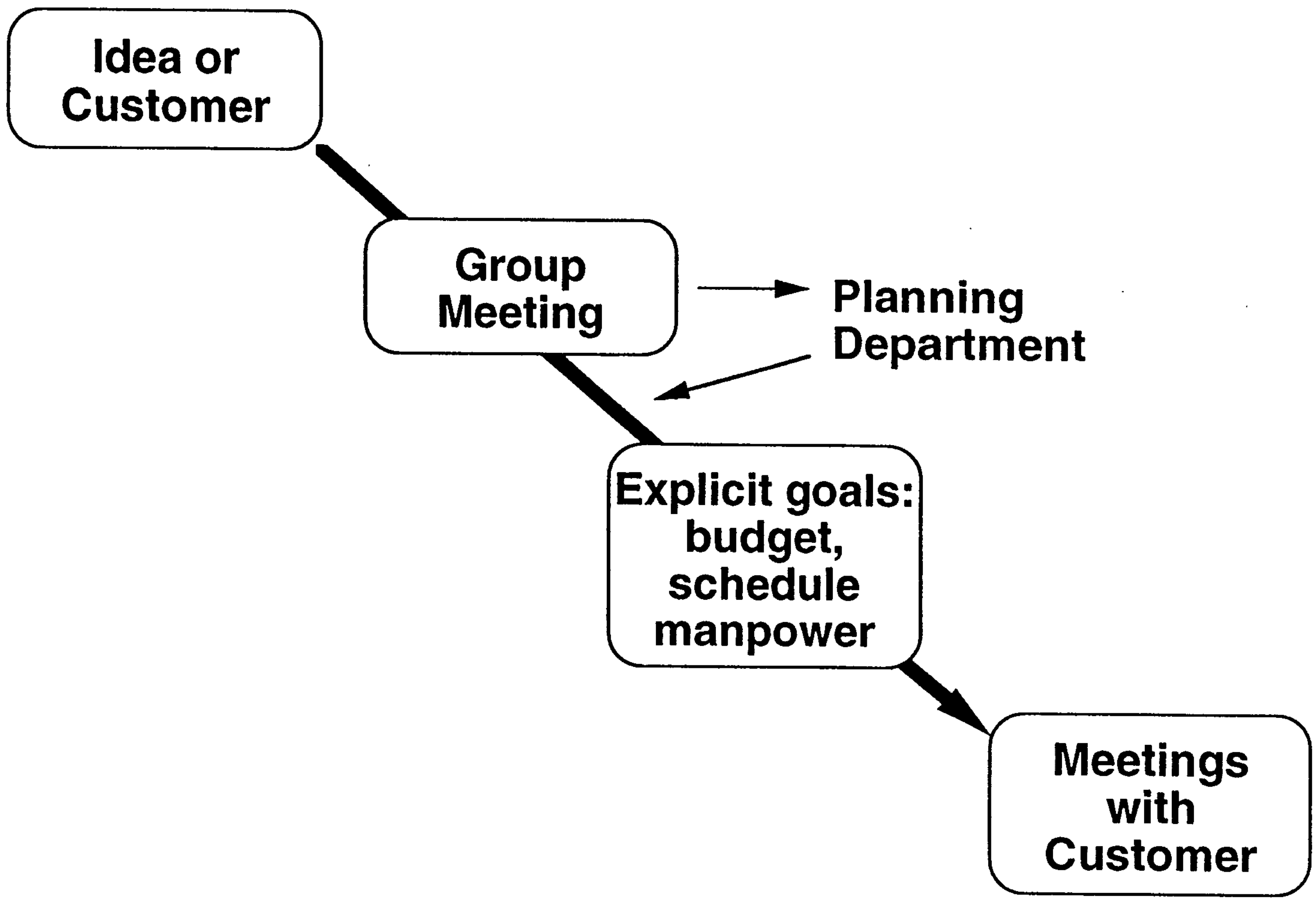


PRODUCT DEVELOPMENT METHODOLOGY



Based on a Case from Nissan

IMPROVEMENT OF SYSTEMS

- New products become realities through
  - new materials
  - new equipment
  - new tooling
  - new designs
  - new tests and methodologies
  - new skills

- Integration leads to larger gains at the "SYSTEMS LEVEL"

- Plan for future replacement
  Steel by composites - Nippon Steel

MANAGEMENT PHILOSOPHY

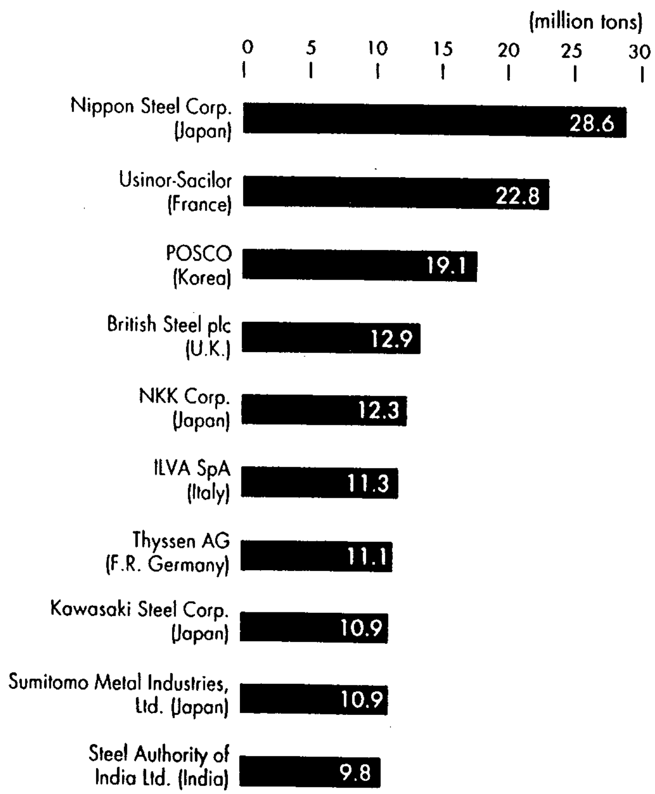
"Like a great river, flowing steadily but changing constantly, the history and work of NIPPON STEEL are a matter of both tradition and transition"

MOVING TOWARDS CHANGE
COMPETING WITH ITSELF

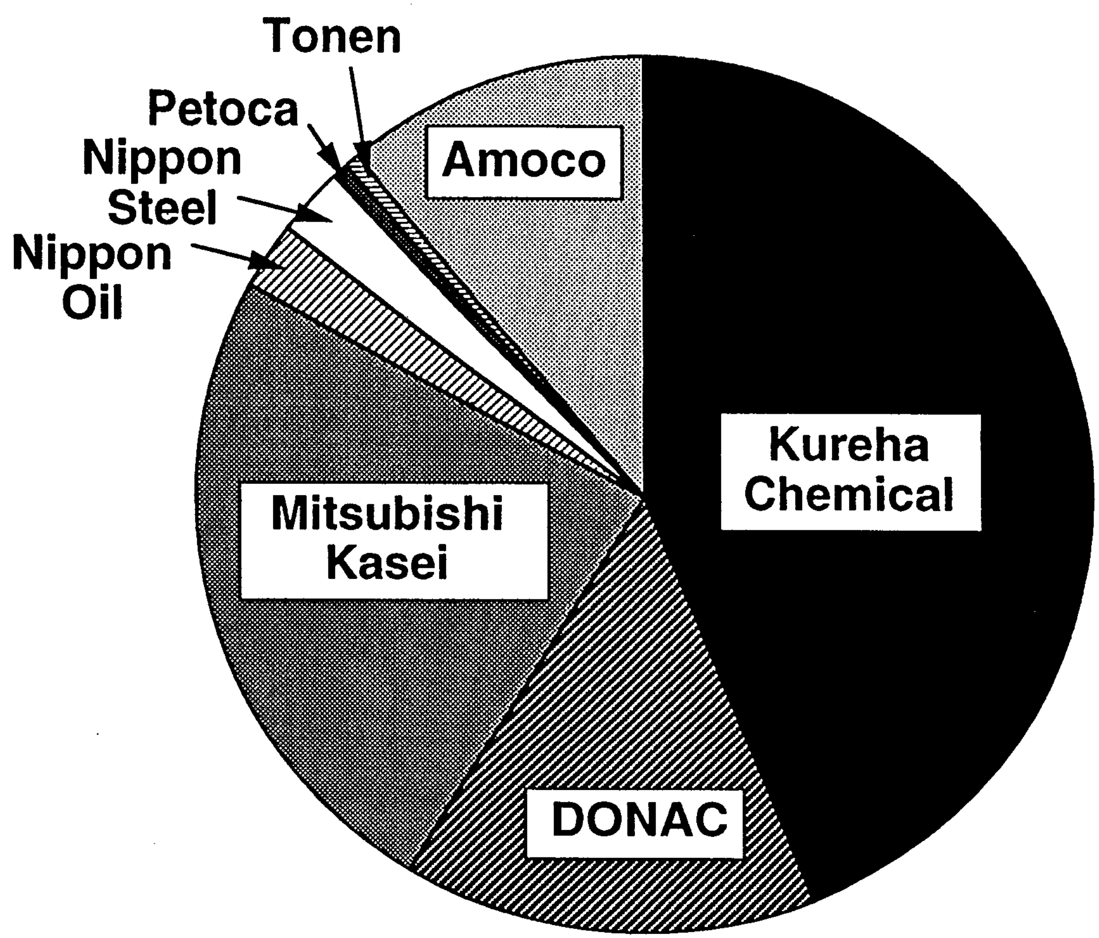
Tradition:	Steel (28.6 million tons in 1991 - largest crude steel producer in the world)
Transition:	New materials (including composites) Currently 25% of total sales Plans to increase it to 40%

Positioning for diversification and replacement in order to hold and expand markets and market share.

PROFILE IN THE WORLD MARKET



Crude Steel Production



Production Capacity of Pitch Carbon Fiber

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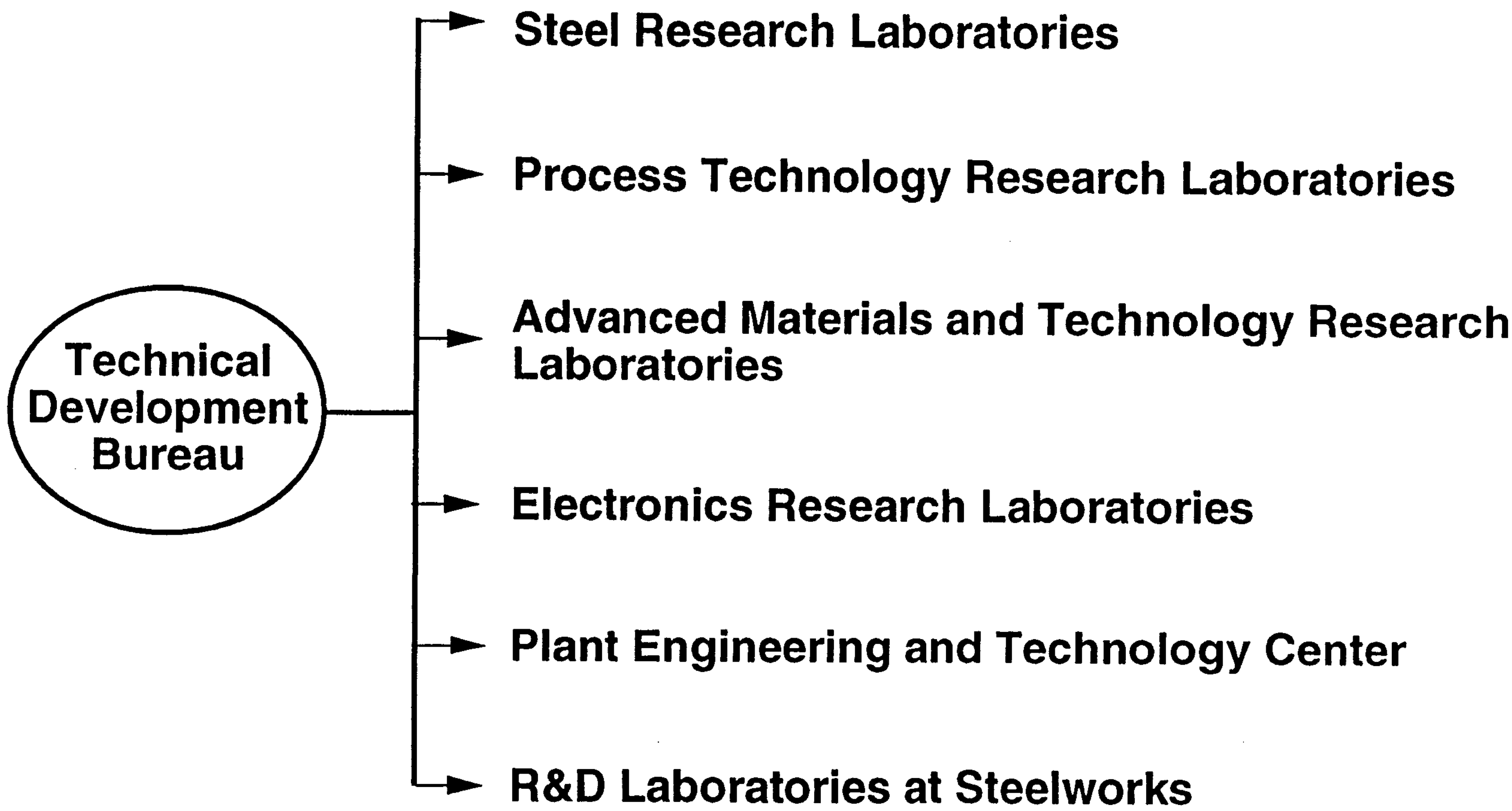
DEVELOPMENT HIERARCHY



FUNDING ALLOCATION

- Budget is allocated to the TDB
- 40% of resources (funding and personnel) are directed by TDB
- 60% of funding is given based on specific recommendations of research groups
- Groups function as independent units with customers following company strategy

RESEARCH FOCUS

- Impetus from the Technical Development Bureau
- Emphasis on linkage and integration from research to engineering
- Early and effective realization of technology is critical

PLANT ENGINEERING AND TECHNICAL CENTER
- practical applications of R&D
- enhancement of equipment and engineering methods

TECHNICAL DEVELOPMENT BUREAU
- promotion of integrated research
- consistent matching of R&D actions with management and business needs
- focus for new ideas

INTERACTIONS BETWEEN RESEARCHERS AND CUSTOMERS

- Generic presentations on materials and/or techniques to customers
- Ideas come up at meetings - jointly
- Developmental work is conducted to prove early viability
- Constant interaction with customer and suppliers
- Trust and committment

BASIC CONCEPTS OF RESEARCH & DEVELOPMENT

R&D + Engineering

R & E

Industrial materials technology

Electronics technology

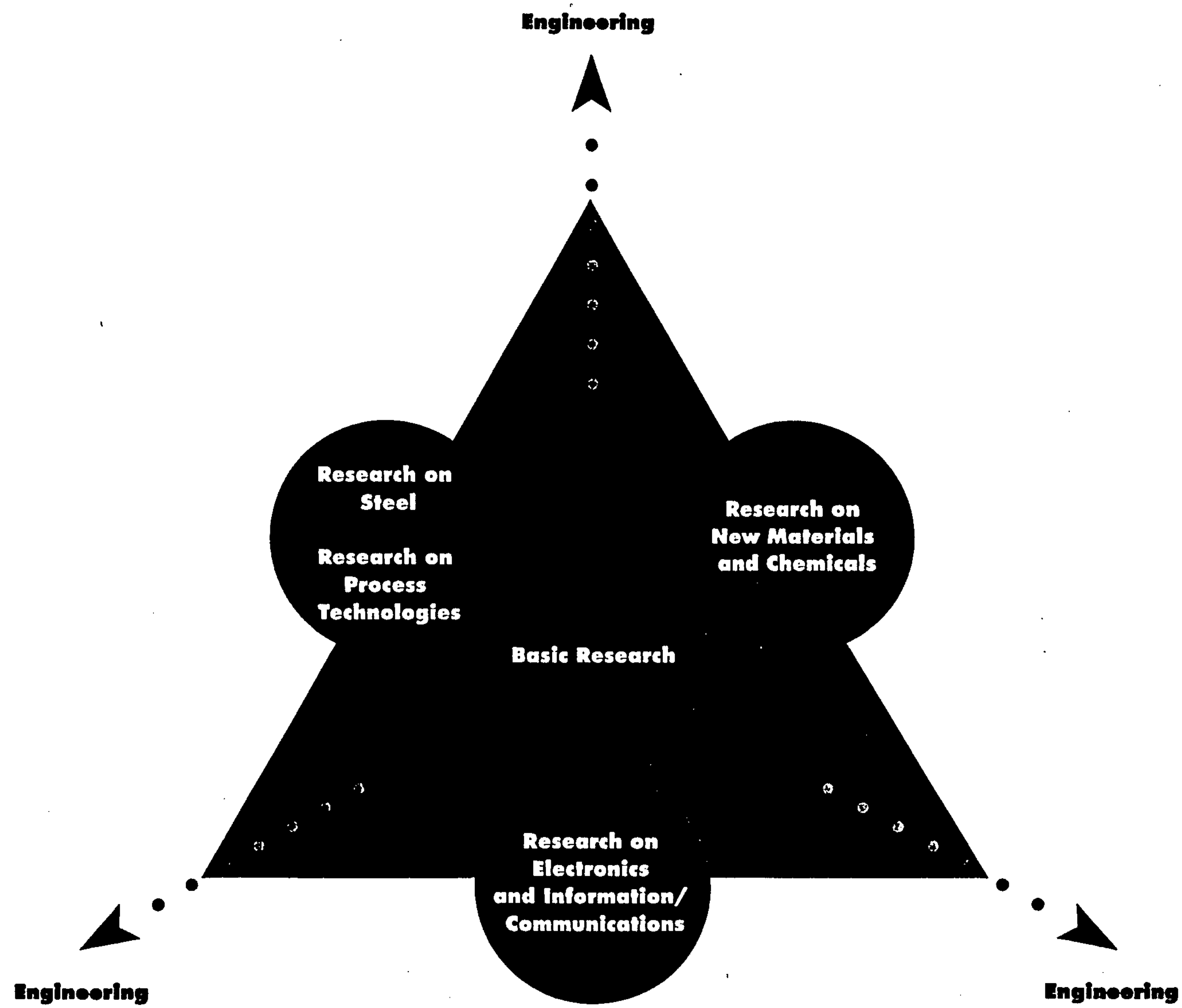
Supporting and other key technologies

Technology Fusion

Breakthrough Technology

R&E
- technological innovation
- blend of product development with process development to create practical and immediate applications

TECHNOLOGY FUSION



ROAD TO INNOVATION

- A more creative labor force
  - emphasis on quality and an intellectual workforce
- Global corporate development
  - management by consensus
  - development of a global viewpoint
- Integration of high technology, information, communications technology and creativity
- Combination of large leaps and small steps in product and process development

LONG-TERM INTERNATIONAL VISION

- Search for new markets
  - increased market share
  - decreasing production costs
- Search for new partners
  - increased risk sharing
  - new ideas
- Search for increased collaboration
  - increased technology transfer (France!!)
  - lock-in of customer base

CONCLUSIONS

- Concurrent engineering is used by definition
- Human factors issues are given prime importance
- Longer development time is allowed
  - greater latitude
- - confidence level
- Products highlifhted through demonstration projects
- Materials development is applications driven
- Individual committment and full management support are the key
- Attention to detail is unnerving
- Information is shared

CONCLUSIONS AND COMPARISONS WITH U.S. ACTIVITY

Panel

Japan vs. U.S. in Advanced Mfg. Technology for Polymer Composite Structures				
	R & D		Production	
	Status	Trend	Status	Trend
Aerospace	—	⇒	—	⇑
Advanced Materials				
Carbon Fiber (Pan)	O	⇒	O	⇒
Carbon Fiber (Pitch)	+	⇑	+	⇑
Thermoset Resin	O	⇒	O	⇑
Thermoplastic Resin	—	⇑		
Processes				
Hand Layup	O	⇒	O	⇑
Auto. Tape Layup	O	⇒	O	⇑
Ply Cutting & Stacking	—	⇑	—	⇑
Filament Winding	—	⇒	—	⇒
Tow Placement	—	⇓	—	⇓
Pultrusion	O	⇑	O	⇑
RTM	O	⇑	O	⇒
Thermoforming	—	⇓		
Co-Curing	+	⇑	+	⇑
Tooling	+	⇑	+	⇑
Sporting Goods	O	⇒	O	⇒
Automotive	—	⇓	—	⇓
Industrial	—	⇓	—	⇓
Civil Engineering	+	⇑	+	⇑

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